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REDLINE VERSION

INTERNATIONAL STANDARD

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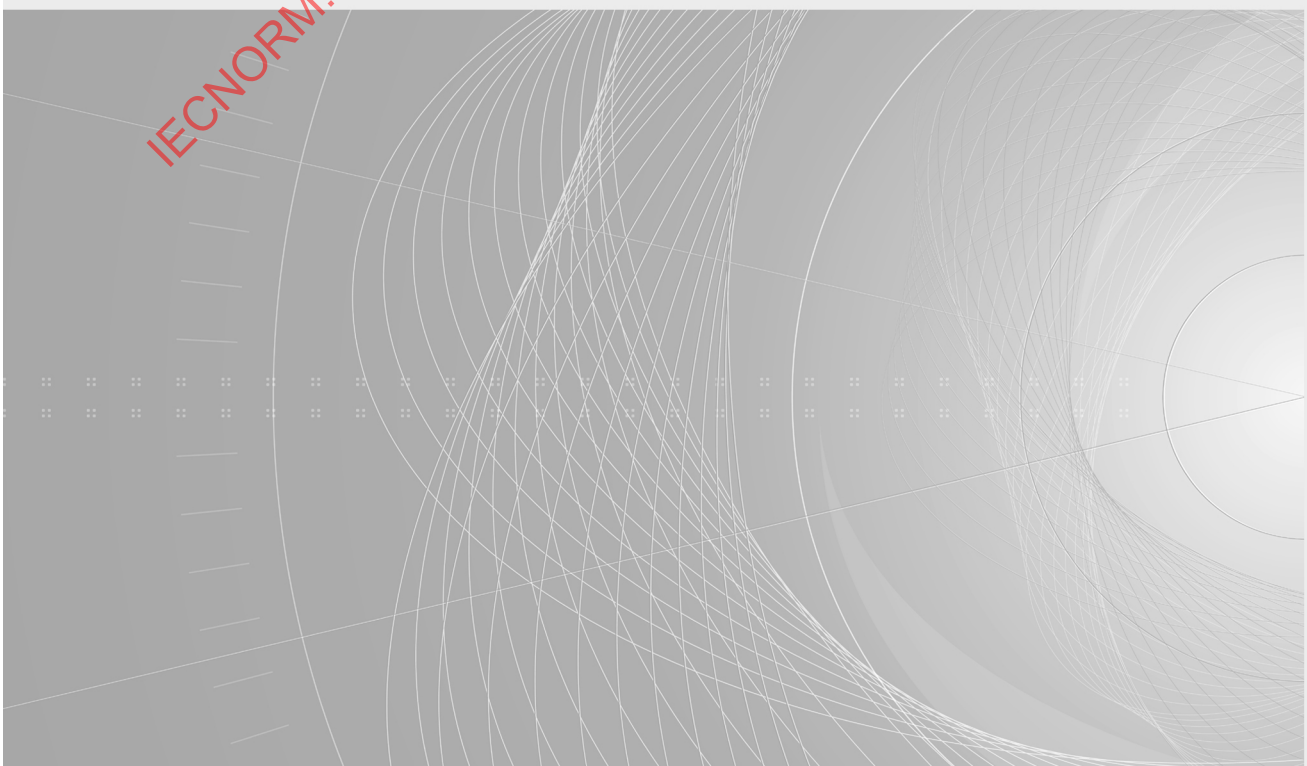
Radiation protection instrumentation – ~~Passive integrating~~ Dosimetry systems with integrating passive detectors for ~~personal~~ individual, workplace and environmental monitoring of photon and beta radiation



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CONTENTS

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RADIATION PROTECTION INSTRUMENTATION – ~~PASSIVE INTEGRATING~~ DOSIMETRY SYSTEMS WITH INTEGRATING PASSIVE DETECTORS FOR ~~PERSONAL~~ INDIVIDUAL, WORKPLACE AND ENVIRONMENTAL MONITORING OF PHOTON AND BETA RADIATION

FOREWORD

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International Standard IEC 62387 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition of IEC 62387 published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- Modification of title.
- Addition of performance requirements for dosemeters to measure $H'(3)$ for both photon and beta radiation.
- Adoption of the cylinder instead of the slab phantom for the quantity $H_p(3)$.
- Correction and clarification of several subclauses to obtain a better applicability.

The text of this standard is based on the following documents:

FDIS	Report on voting
45B/945/FDIS	45B/954/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

A dosimetry system may consist of the following elements:

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

b) a “dosemeter”, that incorporates some means of identification and contains one or more detectors and may contain electronic components, e.g. for the readout (e.g., in a direct ion storage (DIS) dosemeter);

c) a “reader” which is used to readout the stored information (signal) from the detector, in order to determine the radiation dose;

d) a “computer” with appropriate “software” to control the reader, store the signals transmitted from the reader, calculate, display and store the evaluated dose in the form of an electronic file or paper copy;

e) “additional equipment” and documented procedures (instruction manual) for performing associated processes such as deleting stored dose information, cleaning dosemeters, or those needed to ensure the effectiveness of the whole system.

RADIATION PROTECTION INSTRUMENTATION – ~~PASSIVE INTEGRATING~~ DOSIMETRY SYSTEMS WITH INTEGRATING PASSIVE DETECTORS FOR ~~PERSONAL~~ INDIVIDUAL, WORKPLACE AND ENVIRONMENTAL MONITORING OF PHOTON AND BETA RADIATION

1 Scope

This document applies to all kinds of passive dosimetry systems that are used for measuring:

– the personal dose equivalent $H_p(10)$ (for individual whole body ~~dosimetry~~ monitoring),

– the personal dose equivalent $H_p(3)$ (for individual eye lens ~~dosimetry~~ monitoring),

– the personal dose equivalent $H_p(0{,}07)$ (for both individual whole body skin and local skin for extremity ~~dosimetry~~ monitoring),

– the ambient dose equivalent $H^*(10)$ (for workplace and environmental ~~dosimetry~~ monitoring),

– the directional dose equivalent $H'(3)$ (for workplace and environmental monitoring), or

– the directional dose equivalent $H'(0{,}07)$ (for workplace and environmental ~~dosimetry~~ monitoring).

~~NOTE 1 The term "environmental dosimetry" means ambient, area, and environmental monitoring in this standard.~~

This document applies to dosimetry systems that measure external photon and/or beta radiation in the dose range between 0,01 mSv and 10 Sv and in the energy ranges given in Table 1. All the energy values are mean energies with respect to the ~~prevailing dose quantity~~ fluence. The dosimetry systems usually use electronic devices for the data evaluation and thus are often computer controlled.

Table 1 – Mandatory and maximum energy ranges covered by this document

Measuring quantity	Mandatory mean energy range for photon radiation	Maximum mean energy range for testing photon radiation	Mandatory mean energy range for beta-particle radiation[a]	Maximum mean energy range for testing beta-particle radiation[a]
$H_p(10)$, $H^*(10)$	80 keV to 1,25 MeV[b]	12 keV to ~~10~~ 7 MeV	–	–
$H_p(3)$, $H'(3)$	30 keV to 250 keV	8 keV to ~~10~~ 7 MeV	0,8 MeV[c] ~~almost equivalent to an E_{max} of 2,27 MeV~~	0,7 MeV~~[b]~~[c] to 1,2 MeV ~~almost equivalent to E_{max} from 2,27 MeV to 3,54 MeV~~
$H_p(0{,}07)$, $H'(0{,}07)$	30 keV to 250 keV	8 keV to ~~10 MeV~~ 1,25 MeV[b]	0,24 MeV to 0,8 MeV ~~almost equivalent to an E_{max} of 2,27 MeV~~	~~0,06 MeV[c] to 1,2 MeV almost equivalent to E_{max} from 0,225 MeV to 3,54 MeV~~ 0,07 MeV[d] to 1,2 MeV[e]

[a] The following beta radiation sources are suggested for the different mean energies: For 0,06 MeV: ^{147}Pm; for 0,8 MeV: ^{90}Sr/^{90}Y; for 1,2 MeV: ^{106}Ru/^{106}Rh.

[b] 1,25 MeV is the mean energy of photon radiation from ^{60}Co.

~~[b]~~[c] For beta-particle radiation, an energy of 0,7 MeV is required to reach the radiation sensitive layers of the eye lens in a depth of about 3 mm (approximately 3 mm of ICRU tissue).

~~[c]~~[d] For beta-particle radiation, an energy of 0,07 MeV is required to penetrate the dead layer of skin of 0,07 mm (approximately 0,07 mm of ICRU tissue).

[e] 0,07 MeV, 0,8 MeV and 1,2 MeV beta mean energy are almost equivalent to an E_{max} of 0,225 MeV, 2,27 MeV and 3,54 MeV, respectively.

NOTE 21 In this document, “dose” means dose equivalent, unless otherwise stated.

NOTE 32 For $H_p(10)$ and $H^*(10)$ no beta radiation is considered. Reasons:

a) $H_p(10)$ and $H^*(10)$ are a conservative estimate for the effective dose which is not a suitable quantity for beta radiation.

b) No conversion coefficients are available in ICRU 56, ICRU 57 or ISO 6980-3.

NOTE 43 The maximum energy ranges are the energy limits within which type tests according to this document are possible.

NOTE 4 Direct ion storage (DIS) dosemeters are covered in this document as they are often operated without an online display but a separate reader.

The test methods concerning the design (Clause 8), the instruction manual (Clause 9), the software (Clause 10), environmental influences (Clause 13), electromagnetic influences (Clause 14), mechanical influences (Clause 15), and the documentation (Clause 16) are independent of the type of radiation. Therefore, they can also be applied to other dosimetry systems, e.g. for neutrons, utilizing the corresponding type of radiation for testing.

This document is intended to be applied to dosimetry systems that are capable of evaluating doses in the required quantity and unit (Sv) from readout signals in any quantity and unit. The only correction that may be applied to the evaluated dose (indicated value) is the one resulting from natural background radiation using extra dosemeters.

NOTE 5 The correction due to natural background can be made before or after the dose calculation.

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.

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

ISO 4037 (all parts), *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy*

ISO 4037-3:~~1999~~2019, *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*

ISO 6980 (all parts), *Nuclear energy – Reference beta-particle radiation*

ISO 6980-3, *Nuclear energy – Reference beta-particle radiation – Part 3: Calibration of area and personal dosemeters and the determination of their response as a function of beta radiation energy and angle of incidence*

ISO 8529 (all parts), *Reference neutron radiations*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

Several quantities with specific subscripts are explained in Table 6.

~~NOTE The terms are listed in alphabetical order.~~

3.1
ambient dose equivalent
$H^*(d)$
dose equivalent at a point in a radiation field, ~~dose equivalent 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 to entry: The recommended depth, d, for environmental monitoring in terms of $H^*(d)$ is 10 mm, and $H^*(d)$ may be written as $H^*(10)$. ~~[IEV 393-14-95]~~[1]

[SOURCE: ~~ICRU 51:1993, modified – Note 1 to entry has been added~~ IEC 60050-395:2014, 395-05-43 – Note 1 to entry is note 3 in the source]

3.2
calibration coefficient
N_0
quotient of the conventional quantity value to be measured and the corrected indication of the dosemeter, $G_{r,0}$, normalized to reference conditions

_____

~~1 IEC 60050-393 will be replaced by IEC 60050-395.~~

Note 1 to entry: The calibration coefficient for the reference radiation quality U and the angle of incidence α is equivalent to the calibration factor multiplied by the instrument coefficient. It is given by

$$N_0 = \frac{C_{r,0}}{G_{r,0}} = C_f(U,\alpha)\cdot c_i$$

where

$C_{r,0}$ is the conventional quantity value, see 3.5

$G_{r,0}$ is the corrected indication, see 3.14

$C_f(U,\alpha)$ is the calibration factor for the radiation quality U and the angle of incidence α, see 3.3, and

c_i is the instrument constant, see 3.18.

Concerning the dimension of the calibration factor and the calibration coefficient, see notes to 3.3 and 3.18.

Note 2 to entry: The reciprocal of the calibration coefficient is the response under reference conditions. The value of the calibration factor may vary with the magnitude of the quantity to be measured. In such cases a dosemeter is said to have a non-constant response (or a non-linear indication).

[SOURCE: ISO 29661:2012, 3.1.5, modified – Note 3 to entry has been deleted]

3.3
calibration factor
~~N_0~~
~~quotient of the conventional true value of a quantity $C_{r,0}$ and the indicated value $G_{r,0}$ at the point of test for a reference radiation under reference conditions~~

$$N_0 = \frac{C_{r,0}}{G_{r,0}}$$

~~Note 1 to entry: The reciprocal of the calibration factor is equal to the response under reference conditions. In contrast to the calibration factor, which refers to the reference conditions only, the response refers to any conditions prevailing at the time of measurement.~~

~~Note 2 to entry: This definition is of special importance for non-linear dosemeters.~~

~~Note 3 to entry The reference value $C_{r,0}$ for the dose is given in Table 7.~~

~~[SOURCE: ISO 4037-3:1999, Definition 3.2.12, modified – The descriptive statement, the symbol as well as the three original notes have been modified and the original example has been removed]~~

$C_f(U,\alpha)$
factor by which the product of the corrected indication, $G_{r,0}$, and the associated instrument constant, c_i, of the dosemeter is multiplied to obtain the conventional quantity value to be measured under reference conditions

Note 1 to entry: The calibration factor is dimensionless.

[SOURCE:ISO 29661:2012, 3.1.7]

3.4
coefficient of variation
v
ratio of the standard deviation s to the arithmetic mean $\overline{G}$ of a set of n indicated values G_j (indicated value)

$$v = \frac{s}{\overline{G}} = \frac{1}{\overline{G}}\sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(G_j - \overline{G})^2}$$

~~[SOURCE: IEC 60050-394:2007[2], 394-40-14, modified – "indicated values" has replaced "measurements" and the letters representing quantities in the descriptive statement and in the formula have been modified]~~

~~**3.4**~~
~~**conventional true value**~~
~~**conventional true value of a quantity**~~
~~*C*~~
~~value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose~~

~~Note 1 to entry: "Conventional true value" is sometimes called "assigned value", "best estimate of the value", "conventional value" or "reference value".~~

~~[SOURCE: GUM B.2.4]~~

3.5
conventional quantity value
C
quantity value attributed by agreement to a quantity for a given purpose

Note 1 to entry: The conventional quantity value C 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]

3.6
correction for non-linearity
r_n
quotient of the response R_n under conditions where only the value of the dose equivalent is varied, and the reference response R_0

$$r_n = \frac{R_n}{R_0}$$

Note 1 to entry: For a linear dosimetry system, r_n is equal to unity.

3.7
coverage factor
k
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: A coverage factor k is typically in the range 2 to 3.

Note 2 to entry: In case of a normal distribution, using a coverage factor of 2 results in an expanded uncertainty that defines an interval around the result of a measurement that contains approximately 95 % of the distribution of values that could reasonably be attributed to the measurand. For other distributions, the coverage factor may be larger.

[SOURCE: GUM 2.3.6:1995, modified – The symbol k has been added]

~~[2] IEC 60050-394 will be replaced by IEC 60050-395.~~

3.8
detector
radiation detector
apparatus or substance used to convert incident ionizing radiation energy into a signal suitable for indication and/or measurement an apparatus or substance which, in the presence of radiation, provides by either direct or indirect means a signal or other indication suitable for use in measuring one or more quantities of the incident radiation

Note 1 to entry: The detector usually requires a separate reader to read out the signal. That means the detector usually is not able to provide a signal without any external reading process.

Note 2 to entry: A passive detector does not need an external power supply to collect and store dose information.

Note 3 to entry: In IEV, the term reads “radiation detector”.

[SOURCE: ~~IEC 60050-394:2007, 394-24~~ IEC 60050-881:1983, 881-13-01, modified – The term “detector” has been added as the first preferred term]

3.9
deviation
D
difference between the indicated values for the same value of the measurand of a dosimetry system, when an influence quantity assumes, successively, two different values

$$D = G - G_r$$

where

G the indicated value under the effect, and

G_r the indicated value under reference conditions

Note 1 to entry: The original term in IEV 311-07-03 reads “variation (due to an influence quantity)”. In order not to mix up variation (of the indicated value) and variation of the response, in this standard, the term is called “deviation”.

Note 2 to entry: The deviation can be positive or negative resulting in an increase or a decrease of the indicated value, respectively.

[SOURCE: IEC 60050-300-311:2001, 311-07-03, modified – "deviation" has replaced “variation (due to an influence quantity)” and “dosimetry system” has replaced “an indicating measuring instrument, of the values of a material measure” and Notes 1 and 2 to entry have been added]

3.10
directional dose equivalent
$H'(d)$
at a point in a radiation field, dose equivalent that would be produced by the corresponding expanded field, in the ICRU sphere at a depth, d, on the radius in a specified direction

Note 1 to entry: The currently recommended depth, d, ~~in terms of $H'(d)$ is 0,07 mm and $H'(d)$ may be written as $H'(0,07)$. [IEV 393-14-96]~~ for environmental monitoring with respect to local skin and lens of the eye is 0,07 mm and 3 mm, respectively, and $H'(d)$ may be written as $H'(0,07)$and $H'(3)$, respectively.

[SOURCE: ICRU 51:1993, modified – Note 1 to entry has been added]

3.11
dosemeter
radiation meter designed to measure quantities such as an absorbed dose or dose equivalent

Note 1 to entry: In a wider sense, this term is used for meters designed to measure other quantities related to radiation such as exposure, fluence, etc. Such use is deprecated.

Note 2 to entry: This apparatus may require a separate reader to read out the absorbed dose or dose equivalent.

Note 3 to entry: A dosemeter usually consists of a detector and a badge, for example thermoluminescence detector (TLD) badge with filters.

Note 4 to entry: A dosemeter may contain electronic components (e.g. for the readout (e.g. ~~the~~ in a direct ion storage (DIS) dosemeter)).

[SOURCE: IEC 60050-395:2014, 395-05-02, modified – Notes 3 and 4 to entry have been added]

3.12
dosimetry system
dosemeter, reader and all associated equipment and procedures used for assessing the indicated value

3.13
expanded uncertainty
U
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: The expanded uncertainty is obtained by multiplying the combined standard uncertainty by a coverage factor.

Note 2 to entry: A confidence level of 95 % is recommended for the use of this document.

[SOURCE: GUM:1995, 2.3.5]

3.14
indicated value
indication
G
value of the measurand given directly by a measuring instrument on the basis of its calibration curve

Note 1 to entry: In this standard, the indicated value is the one given by the dosimetry systems as the final result of the evaluation algorithm (for example display of the software, print out) in units of dose equivalent (Sv), see 8.2.

~~Note 2 to entry: The indicated value is equivalent to the evaluated value in ISO 12794:2000, Annex D.~~

Note ~~3~~2 to entry: For details, see Annex B.

[SOURCE: IEC 60050-300-311:2001, 311-01-08, modified – The original note has been replaced by new Notes 1, 2 and 3 to entry]

3.15
influence quantity
quantity that is not the measurand but that affects the result of the measurement

Note 1 to entry: For example, temperature of ~~a micrometer used to measure~~ a length measuring instrument.

Note 2 to entry: If the effect on the result of a measurement of an influence quantity depends on another influence quantity, these influence quantities are treated as a single one. In this standard, this is the case for two pairs of influence quantities:

a) radiation energy and angle of incidence,

b) ambient temperature and relative humidity.

[SOURCE: GUM:1995, B.2.10, modified – Examples 1, 2 and 3 have been removed and Notes 1 and 2 to entry have been added]

3.16
influence quantity of type F
influence quantity whose effect on the indicated value is a change in response

Note 1 to entry: An example is radiation energy and angle of radiation incidence.

Note 2 to entry: F stands for factor. The indication due to radiation is multiplied by a factor due to the influence quantity.

3.17
influence quantity of type S
influence quantity whose effect on the indicated value is a deviation independent of the indicated value

Note 1 to entry: An example is the electromagnetic disturbance.

Note 2 to entry: All requirements for influence quantities of type S are given with respect to the value of the deviation D.

Note 3 to entry: S stands for sum. The indication is the sum of the indication due to radiation and due to the disturbance.

3.18
instrument constant
c_i
constant by which the indication of the dosemeter G or – if corrections or a normalization were applied – the corrected indication $G_{r,0}$ is multiplied to convert it to the same unit as the measurand

Note 1 to entry: Adapted from ICRU Report 76.

Note 2 to entry: If the instrument's indication is already expressed in the same unit as the measurand the instrument constant, c_i, is unnecessary. This is the case in this standard.

[SOURCE: ISO 29661:2012, 3.1.17]

3.19
lower limit of the measuring range
H_{low}
lowest dose value included in the measuring range

Note 1 to entry: H_{low} is equivalent to H_0 in ISO 14146:2018.

3.20
mandatory range
mandatory range of use
smallest range specified for an influence quantity or instrument parameter over which the dosimetry system must operate to be in compliance with this document

Note 1 to entry: The mandatory ranges of the influence quantities dealt with in this document are given in the second column of Table 8 to Table 16.

3.21
maximum rated measurement time
t_{max}
longest continuous period of time over which the dose is accumulated and over which all requirements of this document are fulfilled

Note 1 to entry: The maximum rated measurement time depends on the lower limit of the measuring range H_{low}, the fading, and other influences.

Note 2 to entry: The beginning of this period of time can for example be erasing the dose by heating (for TLDs) or a dose reset by means of software (for DIS).

3.22
measured value
M
value that can be obtained from the indicated value G by applying the model function for the measurement

Note 1 to entry: For “model function”, see 3.25.

Note 2 to entry: For details, see Annex B.

3.23
measuring range
range defined by two values of the measurand, or quantity to be supplied, within which the limits of uncertainty of the measuring instrument are specified

Note 1 to entry: In this standard, the measuring range is the range of dose equivalent, in which the requirements of this standard are fulfilled and thus the uncertainty is limited.

[SOURCE: IEC 60050-300-311:2001, 311-03-12, modified – The original note has been replaced by a new Note 1 to entry]

3.24
personal dose equivalent
$H_p(d)$
dose equivalent in soft tissue, at an appropriate depth, d, below a specified point on the body

Note 1 to entry: The recommended depths are 10 mm for penetrating radiation, 3 mm to monitor the eye lens dose, and 0,07 mm ~~for superficial radiation~~ to monitor skin dose. ~~[IEV 393-14-97]~~

Note 2 to entry: Soft tissue means ICRU 4-element tissue, see ICRU Report 39.

[SOURCE: ICRU 51:1993, modified – Notes 1 and 2 to entry have been added]

3.25
model function
mathematical model of the measurement that transforms the (set of) observation(s) into the result of the measurement

Note 1 to entry: The model function combines the indicated value G with the reference calibration ~~factor~~ coefficient N_0, the correction for non-linearity r_n, the l deviations D_p (p = 1..l) for the influence quantities of type S, and the m relative response values r_q (q = 1..m) for the influence quantities of type F. An example of a model function is

$$M = \frac{N_0}{r_n \prod_{q=1}^{m} r_q} \left[G - \sum_{p=1}^{l} D_p \right].$$

A model function is necessary to evaluate the uncertainty of the measured value according to the GUM (see GUM ~~sections~~:1995, 3.1.6, 3.4.1 and 4.1).

Note 2 to entry: The calculations according to the model function are usually not performed, only in the case that specific influence quantities are well known and an appropriate correction is applied.

Note 3 to entry: For details, see Annex B.

3.26
point of test
point in the radiation field at which the conventional ~~true~~ quantity value of the quantity to be measured is known

~~[SOURCE: ISO 4037-3, Definition 3.2.6, modified – Between “at which the” and “conventional” the following has been deleted: “reference point of a dosemeter is placed for calibrating or testing purposes and at which the”]~~

[SOURCE: ISO 29661:2012, 3.1.23, modified – “to be measured” has been added]

3.27
preparation
normal treatment of dosemeters or detectors before a dose measurement, which the dosemeters or detectors are intended to be subjected to in routine use

Note 1 to entry: For example, a procedure to erase stored dose information, reset the dose information by means of software, cleaning~~, which the dosemeters or detectors are intended to be subjected to in routine use~~.

3.28
rated range
rated range of use
specified range of values which an influence quantity can assume without causing a deviation or variation of the response exceeding specified limits

Note 1 to entry: In IEC 60050-300-311:2001, 311-07-05, the term reads “nominal range of use”. In this document, “rated range” is used in order to avoid complicated terms like “the range of use of an influence quantity” but to have terms that are easily readable like “the rated range of an influence quantity”.

Note 2 to entry: Influence quantities can be either of type S or of type F.

[SOURCE: IEC 60050-300-311:2001, 311-07-05, modified – “rated range” has replaced “nominal range” and “deviation or variation of the response” has replaced “variation”; Notes 1 and 2 to entry have been added]

3.29
reader
dosemeter reader
instrument used to read one or more detectors in a dosemeter

Note 1 to entry: Signal of a passive dosemeter can be amount of light, amount of charge, transparency of film and so on. Each type of passive dosemeter thus has very a different type of reader.

Note 2 to entry: The readout can also be taken over by self-reading components of the dosemeter, e.g. within DIS dosemeters.

~~[SOURCE: IEC 60050-394:2007, 394-31-13, modified – The term “dosimeter reader” has been replaced by “reader”, “a dosimeter” has been replaced by “one or more detectors in a dosemeter” and Note 1 to entry has been added]~~

3.30
readout
process of measuring the stored dose information of a detector in a reader

Note 1 to entry: If the dosemeter contains self-reading components, e.g. DIS dosemeters, the resulting signal may be corrected for influences such as temperature, fading, etc.

3.31
reference conditions
set of specified values and/or ranges of values of influence quantities under which the uncertainties admissible for a dosimetry system are the smallest

[SOURCE: IEC 60050-300-311:2001, 311-06-02, modified – After “uncertainties” the words “, or limits of error,” have been deleted and “dosimetry system” has replaced “measuring instrument”]

3.32
reference direction
direction, in the coordinate system of a dosemeter, with respect to which the angle to the direction of radiation incidence is measured in unidirectional fields

[SOURCE: ~~ISO 4037-3:1999, 3.2.7~~ ISO 29661:2012, 3.1.29]

3.33
reference orientation
(dosemeter) orientation for which the direction of the incident radiation coincides with the reference direction of the dosemeter

[SOURCE: ~~ISO 4037-3:1999, 3.2.8~~ ISO 29661:2012, 3.1.31]

3.34
reference point of a dosemeter
physical mark or marks on the outside of the dosemeter (possibly described in the manual) to be used in order to position it with respect to the point of test; if there is no mark or marks on the outside of the dosemeter, the geometric centre of the dosemeter should be taken as the reference point

3.35
reference response
R_0
response for a reference value $C_{r,0}$ of the quantity to be measured under reference conditions

$$R_0 = \frac{G_{r,0}}{C_{r,0}}$$

where $G_{r,0}$ is the corresponding indicated value

Note 1 to entry: The reference response is the reciprocal of the reference calibration ~~factor~~ coefficient.

Note 2 to entry: The reference values for the dose are given in Table 7.

3.36
relative expanded uncertainty
U_{rel}
expanded uncertainty divided by the measurement result

3.37
relative response
r
quotient of the response R and the reference response R_0

$$r = \frac{R}{R_0}$$

3.38
response of a radiation measuring assembly
R
ratio, under specified conditions, given by the relation:

$$R = \frac{G}{C}$$

where

G is the indicated value of the quantity measured by the equipment or assembly under test (dosimetry system), and

C is the conventional ~~true~~ quantity value of this quantity

Note 1 to entry: The value of the response may vary with the dose being measured. In such cases, a dosimetry system is said to be non-linear.

[SOURCE: ~~IEC 60050-394: 2007, 394-40-21~~ IEC 60050-395:2014, 395-03-72, modified – The letters representing quantities have been modified, “value” has been replaced by “indicated value of the quantity”, “(dosimetry system)” has been added and the original notes have been replaced by a new Note 1 to entry]

3.39
result of a measurement
set of values attributed to a measurand, including a value, the corresponding uncertainty, and the unit of the measurand

Note 1 to entry: The central value of the whole (set of values) can be selected as *measured value* M (see 3.22) and a parameter characterizing the dispersion as *uncertainty* (see 3.43).

Note 2 to entry: The result of a measurement is related to the *indicated value given by the instrument* G (see 3.14) and to the values of correction obtained by calibration and by the use of a *model* (see 3.25).

Note 3 to entry: The estimation of M can be based on one or more indicated values.

[SOURCE: IEC 60050-300-311: 2001, 311-01-01, modified – “including a value, the corresponding uncertainty, and the unit of the measurand” has been added, the original Notes 1, 4, and 5 have been deleted, and Notes 1 and 2 to entry have been aligned to terms used in this document]

3.40
signal
S
quantity obtained in a reader after readout of a detector from which the indicated value of the dose equivalent is evaluated

Note 1 to entry: Examples are the charge measured in a photomultiplier tube due to TL-light; the area of a certain region from a glow curve of a TL detector; a fitting parameter evaluated from a glow curve analysis.

Note 2 to entry: In principle, it is possible to obtain more than one signal from one detector (for example several fitting parameters from a glow curve analysis).

Note 3 to entry: Using more than one detector always means using more than one signal.

Note 4 to entry: The “signal” is similar to the “readout value” in ISO 12794:2000, 3.13.

Note 5 to entry: For details, see Annex B.

3.41
standard deviation
experimental standard deviation
s
for a series of n measurements of the same measurand, the quantity s characterizing the dispersion of the results

$$s = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(G_j - \overline{G}\right)^2}$$

where

G_j is the result of the j-th measurement, and

$\overline{G}$ is the arithmetic mean of the n results considered

Note 1 to entry: Considering the series of n values as sample of a distribution, $\overline{G}$ is an unbiased estimate of the mean μ, and s^2 is an unbiased estimate of the variance σ^2 of that distribution.

Note 2 to entry: The expression $s/\sqrt{n}$ is an estimate of the standard deviation of the distribution of $\overline{G}$ and is called the “experimental standard deviation of the mean”.

Note 3 to entry: "Experimental standard deviation of the mean" is sometimes incorrectly called “standard error of the mean”.

[SOURCE: GUM:1995, B.2.17, modified – The preferred term “standard deviation” has been added, as well as the symbol s, and the formula has been modified]

3.42
standard test conditions
conditions represented by the range of values of a set of influence quantities under which a calibration or a determination of response is carried out

Note 1 to entry: Appropriate corrections to reference conditions should be made.

Note ~~1~~2 to entry: Ideally, calibrations should be carried out under reference conditions. As this is not always achievable (e.g. for ambient air pressure) or convenient (e.g. for ambient temperature), a (small) interval around the reference values ~~may be used~~ is acceptable. ~~The deviations of the calibration factor from its value under reference conditions caused by these deviations should in principle be corrected for.~~ Values for the standard test conditions together with the reference conditions are given in Table 7.

Note ~~2~~3 to entry: During type tests, all values of influence quantities which are not the subject of the test are fixed within the interval of the standard test conditions.

[SOURCE: ~~ISO 4037-3:1999, Definition 3.2.3, modified – One note has been subdivided into two and references to tables have been omitted~~ ISO 29661:2012, 3.1.36, modified – Note 3 to entry has been added]

3.43
standard uncertainty
u
uncertainty of the result of a measurement expressed as a standard deviation

Note 1 to entry: Standard uncertainty is a more general term than standard deviation, for example, standard uncertainty may also contain uncertainty contributions evaluated using non statistical methods.

[SOURCE: GUM 2.3.1, modified – Note 1 to entry has been added, as well as the symbol u]

3.44
type test
conformity test made on one or more items representative of the production

[SOURCE: ~~IEC 60050-394:2007, 394-40-02~~ IEC 60050-151:2001, 151-16-16]

3.45
upper limit of the measuring range
H_{up}
highest dose value included in the measuring range

3.46
area monitoring
monitoring in which a workplace or an area in the environment is monitored by taking dose (rate) measurements

Note 1 to entry: Area monitoring is performed in terms of $H'(0,07)$, $H'(3)$ or $H^*(10)$.

Note 2 to entry: Definition orientated at ICRP 103 and ICRP 116.

3.47
workplace monitoring
area monitoring using dose (rate) measurements made in the working environment

Note 1 to entry: Usually contrasted with individual monitoring.

Note 2 to entry: Workplace monitoring is performed in terms of $H'(0,07)$, $H'(3)$ or $H^*(10)$.

3.48
environmental monitoring
area monitoring by the measurement of external dose (rate) in the environment

Note 1 to entry: Environmental monitoring is performed in terms of $H'(0,07)$, $H'(3)$ or $H^*(10)$.

3.49
individual monitoring
monitoring using dose (rate) measurements by equipment worn by individual workers, or measurements of quantities of radioactive material in or on their bodies

Note 1 to entry: Also called personal monitoring. Usually contrasted with workplace monitoring.

Note 2 to entry: Individual monitoring is performed in terms of $H_p(0,07)$, $H_p(3)$ or $H_p(10)$.

[SOURCE: IAEA Glossary:2016, modified – "dose (rate)" has been added and Note 2 to entry has been added]

4 Units and symbols

In this document, units of the international system (SI) are used. Nevertheless, the following units may be acceptable in common usage:

– for energy: electron-volt (symbol eV). 1 eV = 1,602 × 10^{-19} J;
– for time: year, month, day, hour (symbol h), minute (symbol min).

Multiples and submultiples of SI units may be used, according to the SI system.

The SI unit of dose equivalent is 1 J kg^{-1}.

The special name for the unit of the dose equivalent is sievert (symbol Sv). 1 Sv = 1 J kg^{-1}.

A list of symbols is given in Table 6 ~~(at the end of the document)~~.

A list of abbreviations is given in Table 17.

5 General test procedures

5.1 Basic test procedures

5.1.1 Instructions for use

The instructions for use of the dosimetry systems have to be unambiguously given in the manual, see Clause 9. These instructions have to be the same for all parts of the type test and for the routine use as well.

5.1.2 Nature of tests

The tests listed in this document are considered to be type tests, see Annex C.

5.1.3 Reference conditions and standard test conditions

Reference conditions are given in the second column of Table 7 (at the end of the document). The tests shall be carried out under standard test conditions given in the third column of Table 7 unless otherwise specified.

All influence quantities shall be maintained within the limits set for standard test conditions given in Table 7, except for those influence quantities currently under test, unless otherwise specified in the test procedure.

5.1.4 Production of reference radiation

The nature, construction and conditions for the use of ionizing radiation shall conform to the recommendations in the following documents:

a) ISO 4037 series for photon radiation,

b) ISO 6980 series for beta radiation, and

c) ISO 8529 series for neutron radiation.

5.1.5 Choice of phantom for the purpose of testing

For tests involving the use of a phantom, ISO phantoms as described in ISO 4037-3:~~1999, 6.3.1~~ 2019, 7.3.1, shall be used. The required irradiation geometry is specified in the appropriate ISO reference standard (ISO 4037-3 or ISO 6980-3).

5.1.6 Position of dosemeter for the purpose of testing

For tests involving the use of radiation, the reference point of the dosemeter shall be placed at the point of test and the dosemeter shall be oriented in the reference orientation. This is not applicable for tests to determine the response depending on the angle of incidence.

5.2 Test procedures to be considered for every test

5.2.1 Number of dosemeters used for each test

The number n of dosemeters (or irradiations) used for any test need not be the same for each test but may be determined using Annex A. However, it may be convenient to use, arbitrarily, 4, 5, 8, 10 or 20 dosemeters (or irradiations), in which case the Student's t-value, obtained from Annex A, Table A.1, would be 3,18; 2,78; 2,37; 2,26; or 2,09; respectively.

NOTE Using Annex A, the performance requirements are demonstrated to be met to 95 % confidence.

5.2.2 Consideration of the uncertainty of the conventional ~~true~~ quantity value

The relative expanded uncertainty $U_{C,\mathrm{rel}}$ of the conventional ~~true~~ quantity value C of the dose equivalent shall be considered. It shall be less than 8 % at a 95 % coverage interval. The testing laboratory shall determine $U_{C,\mathrm{rel}}$ according to the GUM.

NOTE According to 3.13, the confidence level is 95 %.

5.2.3 Consideration of non-linearity

The effect of a non-linearity due to dose dependence shall be taken into account.

A practical method is to start the tests with the non-linearity and perform the other tests in a dose region where the non-linearity is negligible (1 % to 2 %).

5.2.4 Consideration of natural background radiation

For the measurement of low dose equivalents or at low dose equivalent rates, it is necessary to take into account the contribution of natural background radiation to the dose equivalent. This is usually done by taking a significant number of dosemeters (at minimum 10 dosemeters) as background dosemeters. These are treated in the same way as the ones under test, but not irradiated. The mean indicated value of these dosemeters has to be subtracted from the indicated value of the dosemeters under test.

5.2.5 Consideration of several detectors or signals in a dosemeter

If more than one signal (see 3.40) or detector (see 3.8) is used to evaluate the indicated value, each signal or detector shall be tested separately. Separate tests are necessary when the different signals are used to evaluate the indicated value in different regions of the measuring range or in different regions of an influence quantity.

NOTE ~~1~~ If this applies, this means that the complete amount of testing according to this document is multiplied by the number of signals being used in different ranges.

~~NOTE 2~~

EXAMPLE 1 If a second detector or signal is used to evaluate the dose above a dose equivalent of 200 mSv, for this detector or signal all the requirements according to this document have to be measured within its operating range, i.e. above a dose equivalent of 200 mSv.

EXAMPLE 2 If a second detector or signal is used to evaluate the dose at very low particle energies (for example a very thin detector for low energy beta radiation), for this detector or signal all the requirements according to this document have to be measured within its operating range, i.e. at low particle energies.

5.2.6 Performing the tests efficiently

The effect of several influence quantities is tested by irradiating different groups of dosemeters: one or several test groups on which the effect of the influence quantity is measured and one reference group. For limiting the necessary number of irradiations, it is appropriate to combine the tests given in 11.9 to Clause 15 with only two or three reference groups.

A list of actions necessary to perform a type test according to this document is given in Annex C.

6 Performance requirements: summary

For the following types of dosemeters at least the following quantities shall be measured:

~~– whole body dosemeter: $H_p(10)$ due to photon radiation,~~

~~– extremity dosemeter: $H_p(0,07)$ due to photon and beta radiation,~~

~~– eye lens dosemeter used in pure photon radiation fields: $H_p(0,07)$ or $H_p(3)$ due to photon radiation,~~

~~– eye lens dosemeter used in beta or mixed beta/photon radiation fields: $H_p(3)$ due to beta and photon radiation.~~

– personal whole body dosemeters: $H_p(10)$ due to photon radiation,

– personal eye lens dosemeters used in pure photon radiation fields: $H_p(0,07)$ or $H_p(3)$ due to photon radiation,

– personal eye lens dosemeters used in beta and/or mixed beta/photon radiation fields: $H_p(3)$ due to beta and photon radiation,

– personal extremity dosemeters: $H_p(0,07)$ due to photon and/or beta radiation,

– area dosemeters for estimating effective $H^*(10)$ due to photon radiation,

dose:

- area dosemeters for estimating the dose to the lens of the eye used in pure photon radiation fields: $H'(0,07)$ or $H'(3)$ due to photon radiation,
- area dosemeters for estimating the dose to the lens of the eye used in beta and/or mixed beta/photon radiation fields: $H'(3)$ due to beta and photon radiation,
- area dosemeters for estimating the dose to local skin: $H'(0,07)$ due to photon radiation.

National regulations may require that more quantities be measured by specific types of dosemeters.

NOTE 1 Background information regarding the choice of quantities to be measured for eye lens dosimetry can be found in Behrens and Dietze (2010).

NOTE 2 The term “beta radiation” is used as a synonym for both electron and beta radiation in this document.

The performance requirements for dosimetry systems are given in Tables 8 to 13 depending on the quantity to be measured: $H_p(10)$: Table 8; $H_p(3)$: Table 9; $H_p(0,07)$: Table 10; $H^*(10)$: Table 11; $H'(3)$: Table 12; $H'(0,07)$: Table 13.

Details for some of the entries in Tables 8 to 13 (at the end of the document) are given in the further Tables ~~9~~ 14 to ~~11~~ 16 (at the end of the document).

In some countries the presence of beta dose has to be indicated by dosemeters worn on the trunk. Such an indication of the presence of beta dose is not a measurement. For that reason, a specific subclause (11.9) deals with the indication of the presence of beta dose.

Usually, a dosimetry system is not able to measure all quantities given above. Thus, the system is only tested with regard to those quantities and types of radiation it is intended to be used for. ~~Annex D gives further guidelines to define specific usage categories.~~

Full compliance with this document is given if the requirements for the mandatory ranges given in Tables 8 to 13 are fulfilled. If the customer or manufacturer requires extended ranges then the test should also be performed as specified in this document, i.e. the requirements given in Tables 8 to 13 apply, too. The range of any influence quantity stated by the manufacturer is called rated range. Thus, dosimetry systems can be classified by stating a set of ranges (for example, for dose, for energy, for temperature) within which the requirements stated in this document are met (Capabilities of the system, see Clause 7). ~~In addition, usage categories are given in Annex D with respect to different measuring capabilities.~~

For the dosimetry systems described above, this document specifies general characteristics, general test procedures and performance requirements, radiation characteristics as well as environmental, electrical, mechanical, software and safety characteristics.

A dosimetry system may be tested with regard to different quantities at different times. In case the dosimetry system was changed since the previous test, a new test with regard to quantities tested formerly may be necessary.

The absolute calibration of the dosimetry system is not checked during a type test according to this document as only system properties are of interest. The absolute calibration is checked during a routine test.

7 Capability of a dosimetry system

7.1 General

The ranges described in the following subclauses shall be stated by the manufacturer. They shall be equivalent to or larger than the mandatory ranges that are given in Table 8 to Table 13. The dosimetry system shall fulfil the requirements for these rated ranges.

The rated ranges shall be given in the documentation of the dosimetry system (instruction manual), so the user of the dosimetry system is aware of the capabilities of the instrument.

7.2 Measuring range and type of radiation

Depending on the dose quantity, the limits of the measuring range shall at least cover the mandatory ranges given in line 7 of Table 8 to Table 13.

The type(s) of radiation the dosimetry system is designed for shall be stated.

In case the dosimetry system is not able to measure $H_p(0,07)$ due to beta ~~dose~~ radiation due to all required energies and angles of incidence (that means it does not fulfil ~~11.6.2 or~~ 11.7.2 ~~– whichever applies~~) but is able to indicate the presence of beta dose (that means it does fulfil 11.9) this shall be stated.

7.3 Rated ranges of the influence quantities

The rated range of any influence quantity shall be stated by the manufacturer in the documentation. The mandatory range for each influence quantity is given in the third column of Table 8 to Table 16. All requirements of this document shall be fulfilled over all the rated ranges.

7.4 Maximum rated measurement time t_{max}

The manufacturer shall state the maximum duration of a dose measurement t_{max} during which the requirements of this document are fulfilled. Especially, the requirements on the coefficient of variation shall be fulfilled.

This time shall be at least 1 month.

7.5 Reusability

A dosemeter is considered to be reusable as long as its performance meets the requirements of this document. If the dosemeter cannot be reused indefinitely or if usability depends on the history of the dosemeter, this fact shall be stated by the manufacturer. The manufacturer shall give the limits for repeated uses, ~~e.g. the total number of cycles of use and/or~~ i.e. a maximum dose value to which the dosemeter was exposed above which ~~dosemeters~~ it cannot be reused. Especially, the requirements related to the coefficient of variation shall be fulfilled for all dosemeters that are reused.

NOTE An example of limited reusability is an increase of the zero-signal in a TL detector after receiving a high dose.

7.6 Model function

The manufacturer shall state the general form of the model function for the measurement with the dosemeter. The manufacturer can use the example given in 3.25 or other functions. The manufacturer shall state any interdependencies between the variables of the model function. The variables are the calibration ~~factor~~ coefficient, the relative responses, and the deviations.

NOTE Further details regarding the model function and the determination of uncertainty in measurement are given in IEC TR 62461.

7.7 Example for the capabilities of a dosimetry system

The following numbers are arbitrarily chosen, covering at least the mandatory ranges, and differ from one dosimetry system to another.

The dosimetry system can be used to measure $H_p(10)$ due to photon radiation:

Measuring range: 0,05 mSv $\leq H_p(10) \leq$ 4 Sv. The dosimetry system is able to indicate the presence of beta dose.

The following ranges of use for the different influence quantities are covered.

- Photon energy and angle of incidence: 50 keV to 1,4 MeV and 0° to ± 60°
- Ambient temperature and relative humidity (dosemeters): –15 °C to 50 °C and 40 % to 90 % RH
- Ambient temperature (reader): +10 °C to +40 °C
- Light exposure (dosemeters and reader): up to 1 000 W/m^2
- Electromagnetic disturbances (reader): mandatory ranges, see Table 15
- Mechanical disturbances: mandatory ranges, see Table 16

Maximum rated measurement time: 6 months.

The dosemeters of the dosimetry system are reusable unless irradiated with a dose equivalent exceeding 200 mSv.

Model function: $M = \frac{N_0}{r_n \cdot r_{E,\alpha} \cdot r_{env}} \cdot [G - D_{EMC} - D_{mech}]$

where

M is the measured value;

N_0 is the reference calibration ~~factor~~ coefficient;

r_n is the relative response due to non-linearity;

$r_{E,\alpha}$ is the relative response due to energy and angle of incidence;

r_{env} is the relative response due to environmental influences;

G is the indicated value of the dosimetry system;

D_{EMC} is the deviation due to electromagnetic disturbances;

D_{mech} is the deviation due to mechanical disturbances.

For details see 3.22 and Annex B.

8 Requirements for the design of the dosimetry system

8.1 General

The information required in this Clause 8 shall be documented by the manufacturer for the type test in written form (not necessarily in the instruction manual). The requirements given can easily be checked by visual inspection of the dosimetry system during use.

8.2 Indication of the dose value (dosimetry system)

The indicated value shall be given in units of dose equivalent, for example, microsieverts (μSv). The display or dose record shall also clearly indicate the quantity being measured.

If the reader has range-change facilities, the range-change shall be automatic.

At dose values equal to or larger than ten times the lower limit of the measuring range, i.e. at $H \geq 10 \cdot H_{low}$, the indicated value shall be displayed with a resolution better than 2 %. At the lower limit of the measuring range, H_{low}, a value of 10 % is sufficient.

NOTE A possible technical solution is a digital display: at the lower limit of the measuring range, H_{low}, at least two significant digits are shown. For example, at H_{low} = 0,1 mSv the display shows 0,10 mSv. Above $10 \cdot H_{low}$, three significant digits are shown: 1,00 mSv.

8.3 Assignment of the dose value to the dosemeter (dosimetry system)

Every indicated value shall be distinctively assigned to the dosemeter (number) it is originating from.

NOTE A possible technical solution is: the assignment during unpacking detectors from their dosemeter is done very carefully. After data evaluation, the dosemeter number and the indicated value are combined into one data set that is always handled together.

8.4 Information given on the devices (reader and dosemeter)

The following information shall be clearly visible on the reader, a) to d) and on the dosemeter, a) to g) ~~(on the dosemeter only~~ if enough space is available on the dosemeter~~)~~:

a) an identification to assign the reader and dosemeter to the dosimetry system;

b) the quantity and measuring range that is measured;

c) the type of radiation (for example photon and / or beta) the dosemeter is suitable for;

d) the rated range of particle energy;

~~f~~e) ~~only on the personal dosemeters: if the dosemeter design does permit the user to use the dosemeter in two or more orientations, then the dosemeter shall fulfil the requirements of this standard for all orientations or it shall clearly be stated on the dosemeter that using it in the wrong orientation can cause erroneous results~~
only on personal dosemeters: if it is possible to wear the dosemeter in two or more orientations, then the dosemeter shall fulfil the requirements of this document for all orientations or it shall clearly be stated on the dosemeter which orientation is correct or that using it in the wrong orientation can cause erroneous results;

~~e~~f) only on the dosemeter: the reference point and reference orientation (or in the manual);

g) only on the dosemeter: an identification number that can be read by the user ~~shall always be on the dosemeter~~ (mandatory).

~~h) only on the dosemeter: usage category according to Annex D.~~

NOTE An example for b) to d) is: 0,1 mSv ≤ $H_p(0,07)$ ≤ 3 Sv; 65 keV ≤ E_{ph} ≤ 1,4 MeV; ~~0,2~~ 0,24 MeV ≤ E_{beta} ≤ 0,8 MeV.

8.5 Retention and removal of radioactive contamination (dosemeter)

As far as reasonably practical, the dosemeter should be designed to minimize the retention and facilitate the removal of contamination. A dosemeter may be provided with an additional protective cover, however, the covered dosemeter shall still meet the requirements of this document.

8.6 Algorithm to evaluate the indicated value (dosimetry system)

For the type test according to this document, the manufacturer shall deliver the evaluation algorithm of the indicated value starting from the signal(s) of the detector(s). The documentation shall be in a form that allows a complete understanding of the calculations and/or the decision tree.

If more than one signal is used to evaluate the indicated value, the manufacturer shall provide the option of reading out the separate signals of the detector(s) for the type test.

NOTE ~~1~~ Details to signal, evaluated value and evaluation algorithm are given in Annex B.

~~NOTE 2~~ This algorithm can be confidential and only be used by the testing laboratory for the purpose of type testing.

8.7 Use of dosemeters in mixed radiation fields (dosimetry system)

If a dosemeter is used in radiation fields for which it is not designed, an example is a photon dosemeter being used in a mixed photon/neutron field, the effect of the radiation not intended to be measured shall be stated by the manufacturer in the manual, see Clause 9. In the mentioned example, the neutron radiation is an influence quantity for the dosemeter designed for photon radiation. The manufacturer shall state the response to neutron radiation for thermal neutrons and one or more of the ISO 8529 radionuclide source reference fields.

With this information, the user can determine the influence on the total dose value with the aid of a second dosemeter intended to measure the neutron radiation.

9 Instruction manual

9.1 General

An instruction manual shall be supplied. It shall be marked in such a way that it is unambiguously related to the dosimetry system described. Such instructions for use are to be furnished for each dosimetry system. The instructions for use shall contain the description of the construction, function, operation and manipulation of the dosimetry system and its component parts including the usage of the software used to control the dosimetry system and the stored data.

9.2 Specification of the technical data

Dosimetry system in general:

– manufacturer's name or registered trade mark (if the system is manufactured as a whole);
– type of dosimetry system and principle of operation;
– block diagram of the dosimetry system including hardware, software and data;
– name of the software of the dosimetry system and identification number (see 10.3);
– description of the functionality and all menus and submenus of the software;
– operational details, maintenance and calibration procedures;
– if the evaluation algorithm is not additive, a comment according to Note 3 of 12.1.

Reader:

– manufacturer's name or registered trade mark;
– type of the reader;
– power supply requirements;
– stabilization time of the reader;
– hint to the necessity of flushing the dosemeter or parts of it with gas during readout;
– warning if prolonged storage at high humidity of the air can be detrimental.

Dosemeter:

– manufacturer's name or registered trade mark;

– type of dosemeter;
– type of detector or detectors;
– types of radiation the dosemeter is intended to measure;
– reference point of the dosemeter;
– the reference direction for calibration purposes;
– reference orientation relative to radiation sources and reference orientation with respect to the wearer;
– drawing of the dosemeters including the detectors and filter materials;
– density thickness of walls surrounding the sensitive volumes (mg cm^{-2});
– mass and dimensions of dosemeter;
– method of cleaning and drying the dosemeter;
– method of clearing dose (“zeroing”) of dosemeter.

Dosimetric characteristics:

– measuring quantity;
– measuring range and variation of the response due to non-linearity;
– coefficient of variation depending on the dose equivalent;
– maximum rated measurement time;
– response to natural environmental radiation, see 13.4;
– relative response as a function of radiation energy and angle of incidence (for both beta and photon radiation);
– rated ranges of all other influence quantities and the corresponding variation of the relative response or deviation (see 7.2 to 7.6, an example is given in 7.7);
– relative response due to radiation not intended to be measured (for example neutron radiation), see 8.7;
– ~~usage category for all dosemeters belonging to the dosimetry system, see Annex D.~~

10 Software, data and interfaces of the dosimetry system

10.1 General

The final version of the software shall be available at the beginning of the type test, as a great part of the software test is indirectly covered by the metrological test. For that reason, a change of the data-relevant part of the software after the type test ~~shall be prevented~~ is not permitted (for data-relevant part see below).

NOTE The following requirements are based on the software guide 7.2 of the European cooperation in legal metrology (WELMEC) and are implementing risk class C of guide 7.2. The WELMEC guide can serve as additional information, however, only the requirements given in this Clause 10 are relevant.

The requirements shall prevent any unintended modification of the software or of the data. In addition, any intended modification of the software or of the data with the aid of an editor shall be prevented. At most, one indicated value may be lost due to any change of the software or data.

The requirements are ~~valid~~ to be applied only ~~in case~~ when the dosimetry system is used for official purposes, for example, legally ~~relevant~~ required personal monitoring.

Once the type test according to this document has been started, no data, tables, or software may be changed or deleted.

Testing of the data-relevant part of the software can be a very complex matter. However, it shall not dominate the testing-time. Therefore, a large amount of responsibility is handed over to the manufacturer by using his documentation, see 10.10, to perform the tests. Nevertheless, a few simple practical tests are made to make sure that the functionality is as documented.

10.2 Design and structure of the software

10.2.1 Requirements

The software shall be designed in such a way that it is not affected by other software unless the effect is required for the correct use of the system.

NOTE One possible technical solution is to separate the software into two parts. One part contains all the functions necessary to control the reader and to evaluate, store and display the indicated values, this part is the “data-relevant part”. The other parts of the software, the “non-data-relevant part”, contain for example statistics about the frequency with which certain dose values occur. The data-relevant part has well-defined functions (software interface) that are used to communicate with the non-data-relevant software parts. This technical concept of software separation has the advantage, that the “non-data-relevant part” may be modified without influencing the “data-relevant part”.

10.2.2 Method of test

Documentation: The measures described to protect the software shall be plausible taking into account the type of operating system on the computer.

Practical test: Make sure that the software is an executable file. In case of software separation, see the note to 10.2.1, the different software parts shall be separate files (for example dynamic link libraries (DLLs)).

10.3 Identification of the software

10.3.1 Requirements

The “data-relevant part” of the software (see Note to 10.2.1) shall have an identification. It shall be possible to display this identification while the software is running. This identification can be compared with the one given in the test record or in the user instructions. The identification shall automatically change in case the software is changed (a simple version number is not sufficient).

NOTE 1 In case of a modular code, several identifications can be built for the different modules.

NOTE 2 One possible technical solution is a checksum, at least cyclic redundancy check using a polynomial lengths of 17 bits (CRC-16) with a secret start value hidden in the executable file, built over the software.

10.3.2 Method of test

Documentation: The method to make sure that the software identification is changed by any modification of the software shall be plausible.

Practical test: Make sure that the identifications can be displayed while the software is running as described in the instruction manual and that they are identical to the ones given in the instruction manual.

10.4 Authenticity of the software and the presentation of results

10.4.1 Requirements

Protection shall cover both, unintentional actions (inadvertent wrong operation) and intended actions (manipulation) by means of an editor. In case the software is modified, the program shall abort during start up with a message such as “Software authenticity violated; unauthorized modification of program!”. The results that are presented shall be guaranteed as

authentic, clearly marked as relevant result of the measurement, and clearly separated from additional information.

~~By this requirement, it is excluded that~~ This requirement is to prevent the reader or dosemeter ~~is~~ being operated with software other than the type tested version.

NOTE One possible technical solution is:

The program code is an executable format (.exe). During start-up of the software, a ~~checksum, at least CRC-16 with a secret start value hidden in the executable file, is built over the software~~ digital signature is checked. ~~This checksum is compared with a reference value hidden in the executable code.~~ In case of non-compliance, the software does not start. The window of the running program is refreshed periodically and checks that it is always visible.

10.4.2 Method of test

Documentation: The measures to prevent any change of the software (for example the evaluation of a checksum) shall be plausible. Check that the legally relevant data sets can only be produced by the type tested data-relevant software.

Practical test: Modify a string value (for example “µSv” into “mSv”) in the executable code with the aid of an editor and run the software. If it starts, the requirement is not met. Judge through visual check that additional information on the display or printout cannot be confused with the information belonging to the relevant measurement data and that all relevant data are presented.

10.5 Alarm and stop of system operation under abnormal operating conditions

10.5.1 Requirements

When abnormal operating conditions occur in system components, the operation of the dosimetry system shall be stopped automatically, in addition an alarm alerting the operator shall be present (audible and/or visible). These abnormal operating conditions include those that lead to a faulty reading or loss of dose information, for example, high voltage failure in a photomultiplier tube, a printer running out of paper, heating temperature in a reader falling below or rising above the normal range of operating temperature, a wireless local area network (WLAN) getting out of range, or if the software controlling the measurement is stopped.

Not more than one indicated value shall be lost due to abnormal operating conditions. In case an indicated value does not fulfil the requirements of this document due to the abnormal operating conditions, this value shall be accompanied by an error message. At maximum one value shall be accepted to be wrong per occurrence of abnormal operating condition if a re-evaluation of the dosemeter is not possible. If a re-evaluation is possible the new indicated value shall fulfil the requirements of this document.

10.5.2 Method of test

Documentation: The measures to recognize faulty operation shall be plausible.

Practical test: Simulate some hardware failures during the readout, for example disconnect the power supply for the heating device, put a wireless local area network (WLAN) out of range, or disconnect the data line between the reader and the computer. If more than one indicated value per simulated hardware failure is lost or accompanied by an error message due to the abnormal operating condition, the requirement is not met. If a re-evaluation is possible the new indicated value shall fulfil the requirements of this document.

10.6 Control of input data by the dosimetry system

10.6.1 Requirements

All values used for the determination of the indicated value, for example calibration ~~factors~~ coefficients, dark-current of a photomultiplier or high voltage of a photomultiplier shall be controlled by the dosimetry system.

NOTE One possible technical solution is to ensure that these values fall within fixed ranges of values.

10.6.2 Method of test

Documentation: The method to make sure that the instrument parameters are in their allowed ranges shall be plausible.

Practical test: Try to change some instrument parameters so that they are out of their range, for example the high voltage of the photomultiplier tube or the pressure of the gaseous nitrogen. If more than one detector is read out per simulated range error, the requirement is not met.

10.7 Storage of data

10.7.1 Requirements

a) Instrument parameters: It shall not be possible for the user to modify the instrument parameters (for example calibration ~~factors~~ coefficients, range for the high voltage of a photomultiplier tube). Exception: Modification of instrument parameters shall be possible only via the paths provided by the software (for example calibration measurement or input by authorized user via a password whose default value is defined in the instruction manual and can be changed by the user). A history of the values and changes of all parameters shall be available for the user.

NOTE 1 One possible technical solution is:

All data are combined in well-defined data sets. The whole data set is protected by a ~~checksum~~ digital signature~~, at least CRC-16 with a secret start value hidden in the executable file~~. The software reads the data set, calculates the ~~checksum~~ digital signature and compares it with its nominal value contained in the data set. In case any change in a data set is detected, the data set is marked as invalid by the program and not used any more.

b) Measurement results: All measurement results including all relevant information necessary to trace back to and reconstruct the measurement that generated the stored result (authenticity) shall be recorded or stored without any change automatically after each measurement. This contains at least date and time of the readout, the identification of the dosemeter (for example number) and of the reader, the indicated value and the calibration ~~factors~~ coefficients used. Such documentation may be made either by hardcopy printout or in electronic form on hard disks in connection with software for data display: viewing program which is a “data-relevant program”, see Note to 10.2.1. This software shall not use (for example, display or print) changed data. In addition, the long-term storage shall have a capacity which is sufficient for the intended purpose. The data shall be protected against loss.

NOTE 2 One possible technical solution is:

All data specific for a certain measurement are combined in well-defined data sets and stored in binary format automatically after the measurement. The whole data set is protected by a ~~checksum~~ digital signature~~, at least CRC-16 with a secret start value hidden in the executable file~~. This data set does not have to contain the instrument parameters, only the information where the actual instrument parameters are available, for example file name, location, and date and time of the file. The viewing program reads the stored data~~, calculates the checksum and compares it with its nominal value contained in the data file~~ and checks its digital signature. In case any change in a data set is detected, the data set is marked as invalid by the program and not used any more. The data are stored on two hard drives supervised by a raid-controller. The software activates the write protection of the operating system.

10.7.2 Method of test

Documentation: The way of storing the data and the measures to prevent any change or loss of these data, for example the procedure to evaluate a checksum, shall apparently be effective (for example, it shall cover the entire data set and a formula to calculate the remaining storage capacity shall be applied). All information to trace back to and reconstruct the measurement shall be contained. If a ~~checksum or~~ digital signature is used, the software to read and display the data (viewing program) shall ~~calculate the checksum and compare it to the nominal value contained in the data set~~ check it.

Practical tests:

a) Make sure that all relevant data necessary to reconstruct the measurement are stored in a data file directly after a measurement and that there is no button or menu item to interrupt or disable the automatic storing.

b) Try to modify instrument parameters or indicated values via the software itself. If this is possible without specific knowledge, for example a password or details of the software structure, the requirement is not met.

c) Open a data file with the aid of an editor and modify single bits, then close the file. If the software of the dosimetry system still reads the data file and delivers the modified value, then the requirement is not met.

d) Try to delete a data file from the hard disc using the standard command of the operating system. If this is possible without a warning or without specific knowledge, for example a password or details of the software structure, the requirement is not met.

e) Check that a warning is given and the measurement stops in case the storage is full or removed.

f) In case data are printed out and stored, make sure that both are identical.

For long term storage of data, it is necessary to consider the limited time (for example a few years) special data formats can be read (for example a CD or DVD).

10.8 Transmission of data

10.8.1 Requirements

In case data are transmitted from one device to another (for example from a reader to a PC), these data shall contain all necessary information to further process them correctly. It shall not be possible to modify, delete or add something to these data. In addition, the receiving part of the dosimetry system, for example the computer, shall make sure that the received data are authentic. That means it shall be recognized if the data come from a device other than the reader or dosemeter assigned to the dosimetry system. In case the connection between the transmitting parts is unavailable or delays the transmission, at most one indicated value shall get lost. In case a data set is transmitted incorrectly (in spite of the transmission protocol tried to repeat the transmission until it succeeded) the data set shall not be used.

NOTE One possible technical solution is:

All transmitted data are combined in well-defined data sets including date and time of the generation of the data set, a running number, an identification of the transmitting part, for example serial number of the reader, and the relevant data. The whole data set is protected by a ~~checksum~~ digital signature~~, at least CRC-16 with a secret start value hidden in the executable file~~. The reader encrypts the data transmitted to the software with a key known to the type tested software only (for example its hash code) via a handshake sequence. The receiving part, for example computer, checks the data by making sure that no running number is missing (or double) and that the identification of the transmitting part is the correct one. In case a transmitted data set is incorrect, it is marked as invalid by the program and not used any more.

10.8.2 Method of test

Documentation: All information to trace back to the measurement and for further processing the measurement data shall be contained in the data set. If a ~~checksum or~~ digital signature is

used, the software to receive the data shall ~~calculate the checksum and compare it to the nominal value contained in the data set~~ check it. Secret data (for example key initial value if used) shall be kept secret against spying out with simple tools (hacking). Check that data are digitally signed to ensure their proper identification and authentication.

Practical tests: Spot checks shall show that no relevant data get lost due to a transmission interruption (for example, unplug a cable or put a wireless local area network (WLAN) out of range).

10.9 Hardware interfaces and software interfaces

10.9.1 Requirements

All entered commands or values received via interfaces (for example, user interfaces such as keyboard, software interfaces, barcode scanner, RFID reader, and over the air updates) shall influence the instruments data and functions in an admissible way only. All commands or values have to be defined, i.e. they shall either have a meaning and processing by the instrument shall be possible, or the instrument shall identify them as being invalid. Invalid commands shall not have any effect whatsoever on the data and functions of the instrument.

NOTE 1 In principle it is possible to circumvent a software interface. This can usually be excluded by software separation, see Note to 10.2.1, when the data-relevant part of the software is realized in a separate binary file.

NOTE 2 One possible technical solution is:

User interfaces: A module in the data-relevant software filters out inadmissible commands. Only this module receives commands, and there is no circumvention of it. Any false input is blocked. The user is controlled or guided when inputting commands by a special software module. This guiding module is inextricably linked with the module that filters out the inadmissible commands.

Software interfaces: There is a software module that receives and interprets commands from the interface. This module belongs to the data-relevant software. It only forwards allowed commands to the other data-relevant software modules. All unknown or not allowed commands are rejected and have no impact on the data-relevant software or measurement data.

10.9.2 Method of test

Documentation: The list of commands and parameters that are accepted by the hardware interfaces and software interfaces shall apparently be complete. For example if on the basis of this list and the information concerning the structure of the software it is not possible to perform a calibration, the list cannot be complete.

Practical test: Using the supplied software and the peripheral equipment, carry out practical tests (spot checks) with both documented and undocumented commands and test all menu items if any. If there is any accessory software accompanying the dosimetry system for operating the interface via an additional computer, for some of the commands that are available it shall be checked that the dosimetry system works as documented. In addition, some other commands shall be given. In case the dosimetry system is affected by this, the requirement is not met.

10.10 Documentation for the software test

10.10.1 Requirements

a) Documentation in the instruction manual: All dosimetric relevant parts, menus and submenus of the software including the viewing program to read and display stored data shall be described in the instruction manual, see Clause 9.

b) Documentation for the type test: In addition to the documentation in the manual, the following information shall be given by the manufacturer for the purpose of type testing:

   – a description of the structure of the software including the data-relevant software functions and the meaning of data; in case of software separation a description of the software interface; the measures to protect the software; see 10.2;

   – the method to evaluate the identification; see;10.3;

- the measures to prevent any change of the software and of the presented data and how their authenticity is guaranteed; see 10.4;
- the measures to recognize faulty operation; see 10.5;
- a list of all parameters, their ranges and nominal values, the method to make sure that they are in allowed ranges, where they are stored and how they may be viewed, including their history; see 10.6;
- the way of storing the data automatically; a description of all fields of a data set; the method used for ensuring their authenticity; the management of exceptional cases when storing data (for example full storage); the method of the viewing program to detect corruptions; the measures to prevent any change or loss of the stored data; see 10.7;
- the way of transmitting the data; a description of all fields of a data set; the method used for ensuring their authenticity; the management of exceptional cases when transmitting data (for example cable disconnected); the measures to prevent any change, loss of or addition to transmitted data; see 10.8;
- a description of the software interface, especially which data domains realize the interface; a complete list of commands and parameters that are accepted by the hardware interfaces and software interfaces, including a declaration of completeness of this list and a brief description of each command; see 10.9;
- the necessary characteristics of the operating system and of the hardware of the computer;
- an overview of the security aspects of the operating system, for example, protection, user accounts, or privileges.

~~NOTE~~ This information can be confidential and only be used by the testing laboratory for the purpose of type testing.

10.10.2 Method of test

Documentation: Check that all documentation required in 10.10.1 is completely given and fulfils its purpose.

Practical tests: By using the software during the type test a lot of menus will be used. All of them shall be documented in the instruction manual. The rest of the menus shall be checked by “playing” with the running software and comparing the corresponding parts of the instruction manual. If not all of the menus found in the software and in the instruction manual fit together, the requirement is not met.

11 Radiation performance requirements and tests (dosimetry system)

11.1 General

All influence quantities dealt with in this clause are of type F, see 3.16.

If the dosimetry system uses more than one signal for the evaluation of the indicated value, Clause 12 shall be taken into account. The necessary information for the test according to Clause 12 shall be gained during the tests according to this Clause 11.

If the dosimetry system is intended to measure both photon and beta radiation and if it uses for both types of radiation the same signal for the evaluation of the indicated value, then the same reference radiation quality has to be chosen for both types of radiation.

This meets practice: If only one signal (and thus one detector) is used, only one calibration ~~factor~~ coefficient can be applied which ~~has to be~~ is the same for both photon and beta radiation. Thus, the reference radiation quality ~~has to~~ shall be the same for the dependence on the particle energy, the angle of incidence and the type of radiation.

11.2 Coefficient of variation

The statistical fluctuations of the indicated value shall fulfil the requirements given in line 6 of Table 8 to Table 13.

The test shall be performed together with the test regarding non-linearity. Therefore, the method of test is described in the following 11.3.

11.3 Non-linearity

11.3.1 Requirements

The variation of the response due to a change of the dose equivalent shall not exceed the values given in line 7 of Table 8 to Table 13 over the entire measuring range for photon and/or beta reference radiation.

11.3.2 Method of test

a) Source to be used

The tests shall be performed with radiation from ^{137}Cs or ^{60}Co sources or other radiation qualities specified in the ISO 4037 series. In case the dosemeter has separate detectors for photon and beta radiation, the test shall be performed with a beta source as well, for example ^{90}Sr/^{90}Y. In case the detector signal strongly depends on the particle energy, i.e. $\max(r_{E,\alpha})/\min(r_{E,\alpha}) > 2$, the test shall also be performed using different radiation qualities, e.g. in addition with low energy photon radiation qualities. During the tests, the dosemeter shall be irradiated on the required phantom (see 5.1.5) from the reference direction.

NOTE 1 The irradiations can be done free in air if the correction factor for irradiating free in air instead of on the phantom is applied. This correction factor is specific for the dosemeter under test and the radiation quality used and is therefore determined specifically. Irradiations free in air may be performed at smaller distances resulting in smaller field diameters as the omitted phantom does not have to be illuminated.

b) Tests to be performed

The tests shall be performed separately with photon radiation or beta radiation (the type of radiation for which the dosimetry system is specified).

The response shall be measured for at least ~~three~~ the following dose values ~~in~~: at each limit of each order of magnitude of the measuring range~~. These shall be~~, at approximately ~~20 %, 40 % and 80%~~ 30 % of each full order of magnitude, at the limits of the measuring range and, in addition, in the vicinity of range changes (if known). In total, n repeated measurements at each of the w dose values shall be performed.

NOTE 2 If, for example, the measuring range is from 0.1 mSv up to 2 Sv, the corresponding dose values are 0,1 and 0,3 mSv; 1 and 3 mSv; 10 and 30 mSv; 100 and 300 mSv; 1 Sv and 2 Sv.

For every dose C_i, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

11.3.3 Interpretation of results

If, using the w values of the coefficient of variation and the values of c_1 and c_2 given in Table 2, shows that

- for w – 2 dose values the coefficient of variation is less than c_1 times the limits given in line 6 of Table 8 to Table 13 and
- for the remaining two dose (rate) values – which shall not be adjacent – the coefficients of variation are less than c_2 times the limits given in line 6 of Table 8 to Table 13,

then the requirement of 11.2 is considered to be met.

NOTE 1 This method of test is explained in detail in Brunzendorf and Behrens (2007), see bibliography. It takes into account the fact that it is not possible to measure the coefficient of variation precisely with a reasonable effort. Therefore, the test incorporates the statistical method of a one-sided chi-square-test. A dosimetry system with a

coefficient of variation being equivalent to 0,9-times the required limit passes the test with a probability of about 80 %. A dosimetry system with a coefficient of variation being equivalent to 1,1-times the required limit fails the test with a probability of about 80 %.

NOTE 2 If the interpretation of the results was that "for every dose C_i, the value $s_i / \overline{G}_i$ would not be larger than the required limit given in line 6 of Table 8 to Table 13 (method of test so far), then a dosimetry system with a coefficient of variation being equivalent to 0,9-times the required limit would fail the test with a probability of about 98 %. It can also be explained as: If the method of test "$s_i / \overline{G}_i$ is larger than the required value" is fulfilled with a probability of about 85 %, then the true coefficient of variation will not be larger than 0,63-times the required limit.

~~If, in addition, for each of the nine resulting groups (dose values C_i), the inequality~~

$$0{,}91 - U_{C,\mathrm{com}} \le \left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{\mathrm{com}} \right) \cdot \frac{C_{r,0}}{C_i} \le 1{,}11 + U_{C,\mathrm{com}}$$

~~is valid and~~

$$0{,}95 - U_{C,\mathrm{com}} \le \left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{\mathrm{com}} \right) \cdot \frac{C_{r,0}}{C_i} \le 1{,}05 + U_{C,\mathrm{com}}$$

~~is valid for the restricted range for H'(0,07) and H^*(10) (see line 7 of Tables 11 and 12), then the requirement of 11.3.1 is considered to be met.~~

If, in addition, for each of the resulting groups (dose values C_i), the inequality $r_{\mathrm{min}} - U_{C,\mathrm{com}} \le \left(\frac{\overline{G}_i}{\overline{G}_{\mathrm{r},0}} \pm U_{\mathrm{com}} \right) \cdot \frac{C_{\mathrm{r},0}}{C_i} \le r_{\mathrm{max}} + U_{C,\mathrm{com}}$ is valid, then the requirement of 11.3.1 is considered to be met.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\mathrm{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\mathrm{r},0}}{C_i}$: $U_{C,\mathrm{com}} = \sqrt{U^2_{C,\mathrm{rel;r},0} + U^2_{C,\mathrm{rel};i}}$ with the relative expanded uncertainties $U_{C,\mathrm{rel;\ r},0}$ and $U_{C,\mathrm{rel};\ i}$ of the conventional ~~true~~ quantity values $C_{\mathrm{r},0}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\mathrm{rel;\ r},0}$ and $U_{C,\mathrm{rel};\ i}$ are correlated, this shall be taken into account. For $U_{C,\mathrm{rel}}$, see 5.2.2.

Table 2 – Values of c_1 and c_2 for w different dose values and n indications for each dose value

w	Value of c_1 for n equal							Value of c_2 for n equal						
	4	7	10	15	20	25	∞	4	7	10	15	20	25	∞
5	1,000	1,007	1,009	1,009	1,009	1,009	1	1,499	1,400	1,344	1,290	1,255	1,231	1
6	1,058	1,051	1,046	1,039	1,035	1,032	1	1,572	1,454	1,389	1,326	1,287	1,261	1
8	1,147	1,117	1,100	1,084	1,074	1,067	1	1,687	1,536	1,458	1,383	1,336	1,304	1
10	1,215	1,166	1,141	1,117	1,102	1,092	1	1,772	1,597	1,508	1,423	1,372	1,335	1
12	1,269	1,205	1,173	1,143	1,124	1,112	1	1,840	1,645	1,548	1,455	1,399	1,360	1
14	1,315	1,238	1,200	1,164	1,142	1,128	1	1,895	1,684	1,578	1,480	1,421	1,379	1
16	1,351	1,265	1,222	1,182	1,158	1,142	1	1,940	1,716	1,605	1,502	1,440	1,396	1
18	1,388	1,289	1,242	1,211	1,171	1,153	1	1,980	1,743	1,628	1,409	1,453	1,409	1
20	1,418	1,311	1,259	1,233	1,183	1,164	1	2,015	1,767	1,646	1,394	1,466	1,421	1
25	1,483	1,355	1,295	1,240	1,210	1,186	1	2,081	1,812	1,683	1,563	1,445	1,444	1
50	1,683	1,494	1,407	1,328	1,283	1,252	1	2,275	1,945	1,789	1,646	1,561	1,504	1

11.4 Overload characteristics, after-effects, and reusability

11.4.1 Requirements

The requirements are subdivided into three parts:

a) Recognition of overload

When the dosemeter is irradiated with a high dose as given in line 8 of Table 8 to Table 13, ~~the indicated value shall not be less than H_{up} and~~ the system shall display an indicated dose larger than the upper dose limit of the range of measurement, H_{up}, or an overload message.

b) After-effects

If a dosemeter irradiated to high dose values produces after-effects on any subsequent measurement, suitable measures shall be taken to ensure that the requirements of this document are met in the subsequent measurements.

c) Reusability

If the dosemeters cannot be reused indefinitely or if usability depends on the history of the dosemeter, this fact is stated by the manufacturer, see 7.5. Often, a high dose during the last irradiation negatively affects the reusability.

11.4.2 Method of test

For this test, four groups of dosemeters shall be exposed to a reference source. The tests shall be performed with radiation from ^{137}Cs or ^{60}Co sources or other radiation qualities specified in the ISO 4037 series.

Group 1: reference group: n (≥ 5) dosemeters shall be irradiated with $C_{r,0}$, see Table 7.

Group 2: at least one dosemeter shall be irradiated with a high dose equivalent as given in line 8 of Table 8 to Table 13.

Group 3: n (≥ 10) dosemeters shall be irradiated with a dose equivalent equal to the lower limit of the measuring range, H_{low}.

Group 4: n (≥ 10) dosemeters shall be irradiated with the dose up to which they are reusable. This dose is given by the manufacturer, see 7.5. Then, the usual method to prepare the dosemeters for a new irradiation shall be applied. Finally, the dosemeters shall be irradiated with a dose equivalent equal to the lower limit of the measuring range, H_{low}.

The dosemeters shall be read out in that order.

For every dose value, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

11.4.3 Interpretation of the results

The indicated value of the second group (only one dosemeter) shall be at least the upper limit of the measuring range, H_{up}, or an overload message shall be displayed on the system.

If for the three other groups of dosemeters, the inequality $r_{min} - U_{C,com} \leq \left(\frac{\overline{G_i}}{\overline{G_{r,0}}} \pm U_{com} \right) \cdot \frac{C_{r,0}}{C_i} \leq r_{max} + U_{C,com}$ with r_{min} and r_{max} taken from line 7 of Table 8 to Table 13 is valid and for groups 3 and 4 the value $\frac{s_i}{\overline{G_i}}$ is smaller than the figures given in line 6 of Table 8 to Table 13, then the requirements of 11.4.1 are considered to be met.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel;r,0}} + U^2_{C,\text{rel;}i}}$ with the relative expanded uncertainties $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel;}\,i}$ of the conventional ~~true~~ quantity values $C_{\text{r,0}}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel;}\,i}$ are correlated, this shall be taken into account. For $U_{C,\text{rel}}$, see 5.2.2.

11.5 Radiation energy and angle of incidence for $H_p(10)$ or $H^*(10)$ dosemeters

11.5.1 Photon radiation

11.5.1.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges shall not exceed the values given in line 9 of Table 8 and Table 11 for $H_p(10)$ and $H^*(10)$, respectively.

11.5.1.2 Method of test

The following radiation qualities specified in the ISO 4037 series shall be used:

N-15, N-20, N-30, N-40, N-60, N-80, N-100, N-150, N-200, N-300,
S-Cs (^{137}Cs), S-Co (^{60}Co), R-C (4,4 MeV), R-F (6,7 MeV).

Irradiations shall be performed for the energies and angles of incidence α given in Table 3:

Table 3 – ~~Angular irradiations~~ Angles of incidence of irradiation for $H_p(10)$ and $H^*(10)$ dosemeters

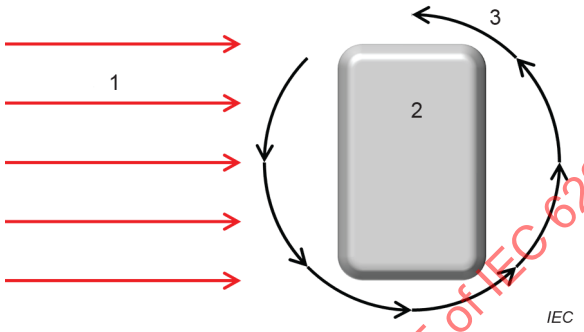
α	$H_p(10)$ dosemeters (irradiations on phantom, see 5.1.5)	$H^*(10)$ dosemeters (irradiations free in air)
0°	For all radiation qualities whose mean energy falls within the rated range of energy	For all radiation qualities whose mean energy falls within the rated range of energy
± 60°	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
± 75°	In case 75° ≤ α_{max}: Three lowest energies in rated range of energy, otherwise not mandatory	For workplace dosemeters with 75° ≤ α_{max} and for environmental dosemeters three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	For environmental dosemeters three lowest energies in rated range of energy
90°	This test is given in 11.8	For environmental dosemeters three lowest energies in rated range of energy
± (180° – α_{max})	No test	As for α_{max}, not necessary if ~~badge~~ the dosemeter is symmetrical
± 105°	No test	As for 75°, not necessary if ~~badge~~ the dosemeter is symmetrical
± 120°	No test	As for 60°, not necessary if ~~badge~~ the dosemeter is symmetrical
180°	No test	As for 0° angle of incidence, not necessary if ~~badge~~ the dosemeter is symmetrical

NOTE 1 The ~~badge~~ dosemeter is symmetrical, if all parts including filters are symmetrical with respect to a plane through the centre of the detector and perpendicular to the reference direction.

NOTE 2 For personal dose quantities: Also take into account 8.4 e) and line 11 of Table 8.

For $\alpha \neq 0°$ and for $\alpha \neq 180°$ the tests shall be performed in two perpendicular planes parallel to the reference direction and going through the reference point of the dosemeter. Different directions for one angle of incidence (for example + 60° and – 60°) shall only be irradiated if the construction of the dosemeter is not symmetrical with respect to a change of that direction.

For $H^*(10)$ dosemeters and $\alpha = 90°$, i.e. the reference direction is orientated perpendicular to the radiation beam, the dosemeter shall be rotated during the irradiation about its reference direction as rotation axis. If no rotation during the irradiation is possible, eight subsequent irradiations with different polar angles in steps of 45° can be ~~done~~ used irradiating the same dosemeter, see Figure 1 for illustration. ~~As α is 90°, the reference direction is orientated perpendicular to the radiation beam.~~



Key

1 Radiation field

2 Dosemeter badge, front face

3 Stepwise rotation in steps of 45° around the reference orientation (perpendicular to the drawing plane)

Figure 1 – Stepwise irradiation of an $H^*(10)$ dosemeter at 90° angle of incidence

For non-symmetrical $H_p(10)$ dosemeters (see Note 1 and 8.4 ~~f~~e)), the dosemeter shall in addition to the normal test be placed on the front side of the phantom with its back to the radiation source (checking whether wearing in the wrong direction gives bad results).

For every radiation quality, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

NOTE ~~2~~3 i refers to a group of dosemeters irradiated equally, for example N-30, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE ~~3~~4 For an $H_p(10)$ dosemeter, for each of the three lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

NOTE ~~4~~5 For an $H^*(10)$ dosemeter, for each of the three lowest radiation energies, at least ten groups of dosemeters are irradiated: one at 0°, four at 60°, four at 75° and one at 90°.

11.5.1.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G_i}}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.5.1.1 is considered to be met. The values for r_{min} and r_{max} are given in line 9 of Table 8 and Table 11.

Exception: In case the expression $\left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{com}\right) \cdot \frac{C_{r,0}}{C_i}$ for 0° angle of incidence differs by only 0,05 or less from the allowed limit and no angular irradiations have been performed at this energy, the corresponding angular irradiations have to be performed for those specific energies.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,com}$ is the combined relative expanded uncertainty of $\frac{C_{r,0}}{C_i}$: $U_{C,com} = \sqrt{U^2_{C,rel;r,0} + U^2_{C,rel;i}}$ with the relative expanded uncertainties $U_{C,rel;\,r,0}$ and $U_{C,rel;\,i}$ of the conventional ~~true~~ quantity values $C_{r,0}$ and C_i for the different radiation qualities, respectively. In case $U_{C,rel;\,r,0}$ and $U_{C,rel;\,i}$ are correlated, this shall be taken into account. For $U_{C,rel}$, see 5.2.2.

11.5.2 Beta radiation

11.5.2.1 Requirements

As the dosemeter is intended to measure $H_p(10)$ or $H^*(10)$, the indicated value due to beta radiation with energies up the energy equivalent of $^{90}Sr/^{90}Y$ shall be less than $0{,}1 \cdot H_p(0{,}07)$ (see line 10 of Table 8 and Table 11).

NOTE For beta radiation, $H_p(10)$ and $H^*(10)$ are not suitable quantities to estimate the effective dose equivalent.

11.5.2.2 Method of test

For this test, ~~the dosemeter shall be placed on a phantom as required (see 5.1.5). Expose~~ n (≥ 4) dosemeters shall be exposed at 0° angle of incidence to beta reference radiation specified in ISO 6980:

– $^{90}Sr/^{90}Y$ (mean energy ≈ 0,8 MeV).

The dose equivalent shall be at least $H_p(0{,}07)$ = 10 mSv = C.

NOTE Details of the reference radiation and the calibration procedure are given in ISO 6980.

For this radiation quality, the mean indicated value $\overline{G}$ and the standard deviation ~~s_i~~ s shall be determined.

11.5.2.3 Interpretation of the results

If $\overline{G} + U_m \leq 0{,}1 \cdot C$ is valid, then requirement of 11.5.2.1 is considered to be met.

U_m is calculated according to formula (A.3).

11.6 Radiation energy and angle of incidence for $H_p(3)$ or $H'(3)$ dosemeters

11.6.1 Photon radiation

11.6.1.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges shall not exceed the values given in line 9 of Table 9 and Table 12 for $H_p(3)$ and $H'(3)$, respectively.

11.6.1.2 Method of test

The following radiation qualities specified in ISO 4037 shall be used:

N-10, N-15, N-20, N-30, N-40, N-60, N-80, N-100, N-150, N-200, N-300, S-Cs (^{137}Cs), S-Co (^{60}Co), R-C (4,4 MeV), R-F (6,7 MeV). ~~As long as no conversion coefficients for the conversion from air kerma, K_a, to personal dose equivalent, $H_p(3)$, are available in ISO 4037-3, the values given in Annex F shall be used.~~

Irradiations shall be performed for the energies and angles of incidence α given in Table 4:

Table 4 – ~~Angular irradiations~~ Angles of incidence of irradiation for $H_p(3)$ and $H'(3)$ dosemeters

α	$H_p(3)$ dosemeters (irradiations on phantom, see 5.1.5)	$H'(3)$ dosemeters (irradiations free in air)
0°	For all radiation qualities whose mean energy falls within the rated range of energy	For all radiation qualities whose mean energy falls within the rated range of energy
± 60°	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
± 75°	In case 75° ≤ α_{max}: Three lowest energies in rated range of energy, otherwise not mandatory	For environmental dosemeters three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	For environmental dosemeters three lowest energies in rated range of energy
90°	This test is given in 11.8	For environmental dosemeters three lowest energies in rated range of energy
± (180°– α_{max})	No test	For environmental dosemeters three lowest energies in rated range of energy
± 105°	No test	For environmental dosemeters three lowest energies in rated range of energy
± 120°	No test	Three lowest energies in rated range of energy
180°	No test	Three lowest energies in rated range of energy

~~NOTE 1 The badge is symmetrical, if all parts including filters are symmetrical with respect to a plane through the centre of the detector and perpendicular to the reference direction.~~

NOTE 1 Also take into account 8.4 e) and line 11 of Table 9.

For $\alpha \neq 0°$ and for $\alpha \neq 180°$, the tests shall be performed in two perpendicular planes parallel to the reference direction and going through the reference point of the dosemeter. Different directions for one angle of incidence (for example + 60° and – 60°) shall only be irradiated, if the construction of the dosemeter is not symmetrical with respect to a change of that direction.

For non-symmetrical $H_p(3)$ dosemeters (see Note 1 and 8.4 ~~f~~e)), the dosemeter shall in addition to the normal test be placed on the front side of the phantom with its back to the radiation source (checking whether wearing in the wrong direction gives incorrect results).

For every radiation quality, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example N-30, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For an $H_p(3)$ dosemeter, for each of the three lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

11.6.1.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.6.1.1 is considered to be met. The values for r_{min} and r_{max} are given in line 9 of Table 9.

Exception: In case the expression $\left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i}$ for 0° angle of incidence differs by only 0,05 or less from the allowed limit and no angular irradiations have been performed at this energy, the corresponding angular irradiations have to be performed for those specific energies.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel;r,0}} + U^2_{C,\text{rel;}i}}$ with the relative expanded uncertainties $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ of the conventional ~~true~~ quantity values $C_{\text{r,0}}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ are correlated, this shall be taken into account. For $U_{C,\text{rel}}$, see 5.2.2.

11.6.2 Beta radiation

11.6.2.1 Requirements

Requirement A: The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges for beta radiation shall not exceed the values given in line 10 of Table 9 and Table 12.

Requirement B: As the dosemeter is intended to measure $H_{\text{p}}(3)$ or $H'(3)$, the indicated value due to beta radiation with energies up the energy equivalent of ^{85}Kr shall be less than $0{,}1 \cdot H_{\text{p}}(0{,}07)$ (see line 10 of Table 9 and Table 12).

11.6.2.2 Method of test

For requirement A:

The following reference radiation qualities specified in ISO 6980 shall be used:

^{90}Sr/^{90}Y (mean energy ≈ 0,8 MeV); ^{106}Ru/^{106}Rh (mean energy ≈ 1,2 MeV).

As long as no conversion coefficients for the conversion from personal absorbed dose in 0,07 mm depth, $D_{\text{p}}(0{,}07)$, to ~~the personal dose equivalent,~~ $H_{\text{p}}(3)$ and $H'(3)$ are available in ISO 6980-3, the values given in ~~Annex G~~ Annex E shall be used.

The tests shall be performed for those radiation qualities whose mean energy falls in the rated range of energy. Angles of incidence shall be: $\alpha = 0°$, $\alpha = \pm 45°$, $\alpha = \pm 60°$ and $\alpha = \pm 75°$ if included in the rated range of angle of incidence in two perpendicular planes containing the reference direction through the reference point of the dosemeter.

For every radiation quality, the mean indicated value $\overline{G}_{i,\text{A}}$ and the standard deviation $s_{i,\text{A}}$ shall be determined.

NOTE 1 Details of the reference radiation and the calibration procedure are given in ISO 6980.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example Sr-90, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For $H_p(3)$ and $H'(3)$ dosemeters, at each of the two lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

For requirement B:

For this test, n (≥ 4) dosemeters shall be exposed at 0° angle of incidence to beta reference radiation specified in ISO 6980:

– ^{85}Kr (mean energy ≈ 0,24 MeV).

The dose equivalent shall be at least $H_p(0,07)$ = 10 mSv = C.

For this radiation quality, the mean indicated value $\overline{G}_B$ and the standard deviation s_B shall be determined.

11.6.2.3 Interpretation of the results

For requirement A:

If, for every radiation quality, the inequality $r_{min} - U_{C,com} \leq \left(\frac{\overline{G}_{i,A}}{\overline{G}_{r,0,A}} \pm U_{com} \right) \cdot \frac{C_{r,0,A}}{C_{i,A}} \leq r_{max} + U_{C,com}$ is valid, then ~~the~~ requirement A of 11.6.2.1 is considered to be met. The values for r_{min} and r_{max} are given in line 10 of Table 9.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,com}$ is the combined relative expanded uncertainty of $\frac{C_{r,0}}{C_i}$: $U_{C,com} = \sqrt{U^2_{C,rel;r,0} + U^2_{C,rel;i}}$ with the relative expanded uncertainties $U_{C,rel;r,0}$ and $U_{C,rel;i}$ of the conventional ~~true~~ quantity values $C_{r,0}$ and C_i for the different radiation qualities, respectively. In case $U_{C,rel;r,0}$ and $U_{C,rel;i}$ are correlated, this shall be taken into account. For $U_{C,rel}$, see 5.2.2.

For requirement B:

If $\overline{G}_B + U_m \leq 0{,}1 \cdot C$ is valid, then requirement B of 11.6.2.1 is considered to be met.

U_m is calculated according to formula (A.3).

11.7 Radiation energy and angle of incidence for $H_p(0,07)$ or $H'(0,07)$ dosemeters

11.7.1 Photon radiation

11.7.1.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges shall not exceed the values given in line 9 of Table 10 and Table 13 for $H_p(0,07)$ and $H'(0,07)$, respectively.

11.7.1.2 Method of test

The following radiation qualities specified in ISO 4037 shall be used:

N-10, N-15, N-20, N-30, N-40, N-60, N-80, N-100, N-150, N-200, N-300, S-Cs (^{137}Cs), S-Co (^{60}Co), R-C (4,4 MeV), R-F (6,7 MeV). ~~As long as no conversion coefficients for the~~

~~conversion from air kerma, K_a, to personal dose equivalent, $H_p(0,07)$, and to directional dose equivalent, $H'(0,07)$, are available in ISO 4037-3 for S-Cs, S-Co, R-C, and R-F the values given in Annex F shall be used.~~

Irradiations shall be performed for the energies and angles of incidence α given in Table 5:

Table 5 – ~~Angular irradiations~~ Angles of incidence of irradiation for $H_p(0,07)$ and $H'(0,07)$ dosemeters

α	$H_p(0,07)$ dosemeters (irradiations on phantom, see 5.1.5)	$H'(0,07)$ dosemeters (irradiations free in air)
0°	For all radiation qualities whose mean energy falls within the rated range of energy	For all radiation qualities whose mean energy falls within the rated range of energy
± 60°	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
± 75°	In case 75° ≤ α_{max}: Three lowest energies in rated range of energy, otherwise not mandatory	For environmental dosemeters three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	For environmental dosemeters three lowest energies in rated range of energy
90°	This test is given in 11.8	For environmental dosemeters three lowest energies in rated range of energy
± (180° – α_{max})	No test	For environmental dosemeters three lowest energies in rated range of energy
± 105°	No test	For environmental dosemeters three lowest energies in rated range of energy
± 120°	No test	Three lowest energies in rated range of energy
180°	No test	Three lowest energies in rated range of energy

~~NOTE 1 The badge is symmetrical, if all parts including filters are symmetrical with respect to a plane through the centre of the detector and perpendicular to the reference direction.~~

NOTE 1 For personal dose quantities: Also take into account 8.4 e) and line 11 of Table 10.

For $\alpha \neq 0°$ and for $\alpha \neq 180°$, the tests shall be performed in two perpendicular planes parallel to the reference direction and going through the reference point of the dosemeter. Different directions for one angle of incidence (for example + 60° and – 60°) shall only be irradiated, if the construction of the dosemeter is not symmetrical with respect to a change of that direction.

For $H'(0,07)$ dosemeters and $\alpha = 90°$, the dosemeter shall be rotated about its reference direction during the irradiation. If no rotation is possible, eight subsequent irradiations with different polar angles in steps of 45° can be done irradiating the same dosemeter. As α is 90°, the reference direction is orientated perpendicular to the radiation beam. The rotation may be omitted if the dosemeter has a holder defining the orientation with respect to the expected direction of radiation incidence.

For non-symmetrical $H_p(0,07)$ dosemeters (see Note 1 and 8.4 ~~f~~e)), the dosemeter shall in addition to the normal test be placed on the front side of the phantom with its back to the radiation source (checking whether wearing in the wrong direction gives incorrect results).

For every radiation quality, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example N-30, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For an $H_p(0,07)$ dosemeter, for each of the three lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

NOTE 4 For an $H'(0,07)$ dosemeter, for each of the three lowest radiation energies, at least ten groups of dosemeters are irradiated: one at 0°, four at 60°, four at 75° and one at 90°.

11.7.1.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.7.1.1 is considered to be met. The values for r_{min} and r_{max} are given in line 9 of Table 10 and Table 13.

Exception: In case the expression $\left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i}$ for 0° angle of incidence differs by only 0,05 or less from the allowed limit and no angular irradiations have been performed at this energy, the corresponding angular irradiations have to be performed for those specific energies.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel;r,0}} + U^2_{C,\text{rel},i}}$ with the relative expanded uncertainties $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ of the conventional ~~true~~ quantity values $C_{\text{r,0}}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ are correlated, this shall be taken into account. For $U_{C,\text{rel}}$, see 5.2.2.

11.7.2 Beta radiation

11.7.2.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges for beta radiation shall not exceed the values given in line 10 of Table 10 and Table 13.

In case these requirements are not met, the requirements given in 11.9 shall be met.

NOTE Subclause 11.7.2 deals with the measurement of beta dose. Subclause 11.9 deals with the indication of the presence of beta dose.

11.7.2.2 Method of test

The following reference radiation qualities specified in ISO 6980 shall be used:

^{147}Pm (mean energy ≈ 0,06 MeV); ^{204}Tl or ^{85}Kr (mean energy ≈ ~~0,2~~ 0,24 MeV);

^{90}Sr/^{90}Y (mean energy ≈ 0,8 MeV); ^{106}Ru/^{106}Rh (mean energy ≈ 1,2 MeV).

As long as no conversion coefficients for the conversion from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the personal dose equivalent, $H_p(0,07)$, are available in ISO 6980-3 for ^{106}Ru/^{106}Rh, the values given in ~~Annex G~~ Annex E shall be used.

The tests shall be performed for those radiation qualities whose mean energy falls in the rated range of energy. Angles of incidence shall be: $\alpha = 0°$, $\alpha = \pm 45°$, as well as $\alpha = \pm 60°$ and $\alpha = \pm 75°$ if included in the rated range of angle of incidence in two perpendicular planes containing the reference direction through the reference point of the dosemeter.

For every radiation quality, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

NOTE 1 Details of the reference radiation and the calibration procedure are given in ISO 6980.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example Kr-85, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For an $H_p(0,07)$ dosemeter, at the lowest or at each of the two lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

11.7.2.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G_i}}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.7.2.1 is considered to be met. The values for r_{min} and r_{max} are given in line 10 of Table 10 and Table 13.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel;r,0}} + U^2_{C,\text{rel;}i}}$ with the relative expanded uncertainties $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ of the conventional ~~true~~ quantity values $C_{\text{r,0}}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ are correlated, this shall be taken into account. For $U_{C,\text{rel}}$, see 5.2.2.

11.8 Over ~~response~~ indication due to radiation ~~incidence~~ incident from the side of an $H_p(10)$, $H_p(3)$ or $H_p(0,07)$ dosemeter

11.8.1 Requirements

If the dosemeter is irradiated free in air from the side (α_{max} to 180°–α_{max}), the indicated value shall not exceed ~~1,5 times (or~~ 2 times~~)~~ the indicated value resulting from an irradiation free in air with the same radiation quality from the front (0°) ~~for $H_p(10)$ and $H_p(3)$ dosemeters (for $H_p(0,07)$ dosemeters, the factor of 2 applies)~~. This shall apply to all radiation energies within the rated range of energy.

NOTE 1 This requirement prevents the acceptance of a detector with a high atomic number material without sufficient shielding which may cause a large over response from the side.

NOTE 2 If α_{max} = 60°, this means an irradiation from 60° to 120°.

NOTE 3 No lower limit is required as the conventional quantity value is zero for beta radiation and for low energy photon radiation.

11.8.2 Method of test

For several radiation energies, the test can be performed by examining the materials in front of the detector(s) and the surrounding material. If it can be anticipated due to physical absorption coefficients that the material at the side results in more absorption than in the front, the tests can be omitted for these radiation energies.

For the remaining radiation energies, irradiations shall be performed for those polar angles β (regions of the side of the badge) at which the surrounding material does not seem to be thick enough. At these “weak points”, at least two groups of dosemeters shall be irradiated free in air to an ambient dose equivalent of $H^*(10) \approx 3$ mSv:

Group 1: The dosemeters shall be irradiated at an angle of incidence of 0°.

Further groups: Irradiations shall be performed at the angle of incidences β corresponding to the “weak points”. The azimuthal angle of incidence shall be varied

during the irradiation between α_{max} and 180°–α_{max} in steps of ~~10~~ 15° including 90° resulting in the indicated value $\overline{G}_{\alpha_{max}\,to\,180°-\alpha_{max}}$.

Separate groups shall be irradiated separately for every polar angle β (i.e. for every "weak point").

NOTE In case of α_{max} = 60°, the irradiation of each badge is performed in ~~five equivalent fractions at 70°, 80°, 90°, 100°, and 110°~~ three equivalent fractions at 75°, 90°, and 105°.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

11.8.3 Interpretation of the results

~~If the inequality~~ $\frac{\overline{G}_{\alpha_{max}\,to\,180°-\alpha_{max}}}{\overline{G}_{0°}} + U_{com} \leq 1{,}5$ ~~is valid for $H_p(10)$ and $H_p(3)$ dosemeters or~~ $\frac{\overline{G}_{\alpha_{max}\,to\,180°-\alpha_{max}}}{\overline{G}_{0°}} + U_{com} \leq 2$ ~~is valid for $H_p(0{,}07)$ dosemeters, then the requirement of 11.8.1 is considered to be met.~~

If, for every polar angle examined in accordance with 11.8.2, the inequality $\frac{\overline{G}_{\alpha_{max}\,to\,180°-\alpha_{max}}}{\overline{G}_{0°}} + U_{com} \leq 2$ is valid, then the requirement of 11.8.1 is considered to be met.

U_{com} is calculated according to formula (A.5), Example 2. This calculation presumes that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

11.9 Indication of the presence of beta dose for $H_p(0{,}07)$ whole body dosemeters

The requirements, method of test, and interpretation of the results stated in 11.7.2 apply for angles of incidence of 0°, see line 13 of Table 10. For angles of incidence of $\alpha = \pm 45°$ the response values shall be measured and stated.

12 Response to mixed irradiations (dosimetry system)

12.1 Requirements

The following requirement is fulfilled for dosimetry systems using only ~~one signal and thus only one detector to evaluate the indicated value. If more than one signal is used and the algorithm used to evaluate the indicated value is either a linear combination of the signals or a linear optimization of them~~ linear combinations or linear optimizations to obtain the signal and finally the indicated value, this requirement is fulfilled and no tests are required (the algorithm is an additive one).

Otherwise, e.g. if any branching or decision points from which on different methods (or equations or corrections) are used in the algorithm, the test shall be performed in order to check the evaluation algorithm of the dosimetry system for mixed irradiations. Mixed irradiation means that a dosemeter is irradiated with two portions of dose equivalent with different radiation qualities or other conditions. The difference in the radiation qualities or other conditions can be

a) a difference in the dose values, and / or

b) a difference in the value of one specific influence quantity (for example different energy and angle of radiation incidence), or

c) a different type of radiation if the dosimetry is tested with respect to more than one type of radiation.

Requirement: The relative response to mixed irradiation shall be within the range of response weighted with the respective dose values.

NOTE 1 This requirement ensures that the results of the test according to this document are also valid if the dosemeter is irradiated with broad spectra and/or mixtures of several radiation qualities.

NOTE 2 A radiation quality in this context is given by the notation according to ISO 4037 or ISO 6980 and the angle of incidence, for example N-30 and 45° angle of incidence.

NOTE 3 A dosimetry system with a non-additive evaluation algorithm can have, although it is in line with this document, the following characteristic: Two dosemeters (A and B) are irradiated with the same dose equivalent (for example 20 mSv) of one radiation quality (for example ^{137}Cs, 0°). Afterwards, dosemeter A is irradiated additionally with another radiation quality (for example 2 mSv, N-40, 0°). The indicated value of dosemeter A (for example 21 mSv) can be smaller than the one of dosemeter B (for example 22 mSv). For both dosemeters, the relative response is within the required range from 0,71 up to 1,67 (i.e. the requirement of 11.5.1 is fulfilled), but the indicated value is not additive.

12.2 Method of test

12.2.1 General

This test has to be performed via calculations using the signals of the dosemeter elements and the evaluation algorithm of the dosimetry system. Therefore, the testing laboratory needs access to the evaluation algorithm and the signals S_g of the dosemeters' elements.

12.2.2 Preparation of the test

The relative responses of the signals of the dosemeter elements gained during the tests according to 11.5, 11.6, and 11.7 shall be used. All radiation qualities listed in 11.5.1.2, 11.6.1.2, 11.6.2.2, 11.7.1.2, and 11.7.2.2 (depending on the type of dosemeter) and all angles of incidence from 0° up to the maximum rated angle in steps of 15° shall be taken into account. In case the dosemeter badge is not symmetrical four different directions (up, down, left, and right) shall be taken into account for every angle of incidence.

In case the relative responses of the signals of the dosemeter elements are not available for all radiation qualities and angles of incidence, these values can be determined by measurements or via Monte Carlo methods, the latter having to be validated by measurements.

In order to make sure that the evaluation algorithm supplied by the manufacturer is correct, the following test shall be done for a few radiation qualities for which irradiations were performed during the tests according to subclause 11.5, 11.6, and 11.7: The indicated value G_K evaluated by the dosimetry system shall be compared to the corresponding indicated value $f(S_{g,K})$ calculated using the signals $S_{g,K}$ of the $g = 1..b$ detector elements and the evaluation algorithm. The values have to be equal, otherwise the manufacturer shall deliver the correct function $f(S_g)$ for the evaluation of the indicated value.

12.2.3 Practical test

Mixed irradiations using the two radiation qualities K and L can be simulated by calculating the sum of the signals $S_{g,K} + S_{g,L}$ for each detector element g. From this sum, the indicated value $G_{K+L} = f(S_{g,K} + S_{g,L})$ for the mixed irradiation condition K+L with the conventional ~~true~~ quantity dose value $C_{K+L} = C_K + C_L$ shall be calculated. The indicated value $G_{K+L} = f(S_{g,K} + S_{g,L})$ shall be determined for any possible combination of two radiation qualities K and L with different energy and angle of incidence within the rate range. For every combination of K and L, the ratio of C_K to C_L shall take the following values: 1:9, 2:8, .. up to 9:1 (nine different ratios). The total dose shall be within the standard test conditions, see line 1 of Table 7.

The relative response shall be calculated according to $r = \frac{G_{K+L}}{C_{K+L}} \cdot \frac{C_{r,0}}{G_{r,0}}$ for every combination described above. In ~~Annex H~~ Annex F, a computational method to perform all these calculations is described.

NOTE As an example, the rated range goes for photons from 33 keV up to 1,25 MeV and from 0° up to ± 60° and for betas from ~~0,2~~ 0,24 MeV up to 0,8 MeV and from 0° up to ± 60°. According to subclauses 11.7.1.2 and 11.7.2.2 nine photon radiation qualities and two beta radiation qualities are involved. In addition, 17 different angles of incidence have to be considered: 0°, 15°, 30°, 45°, and 60°, the latter four from four different directions (up, down, left, right) as the dosemeter badge is assumed not to be symmetrical in any direction. In summary, (9+2) energies times 17 angles of incidence ~~times 9 dose ratios~~ result in ~~1 683~~ 187 contributions of different radiation qualities. The combination of each contribution with each other leads to ~~1 683·1682/2 = 1 415 403~~ 187·186/2 = 17 391 combinations. 17 391 combinations times 9 dose ratios result in 15 6519 types of signals to get the indicated value.

12.3 Interpretation of the results

All the calculated relative responses shall be within the permitted variation of the response. In case different response ranges are required for the different radiation qualities K and L, the range of response weighted with the respective dose values, C_K and C_L, shall be applied. The weighted response shall be calculated as follows: The response ranges for the radiation qualities K and L, $r_{min,K}$ .. $r_{max,K}$ and $r_{min,L}$ .. $r_{max,L}$, shall be combined to the weighted limits for the response values $r_{min,w} = \frac{r_{min,K} \cdot C_K + r_{min,L} \cdot C_L}{C_K + C_L}$ and $r_{max,w} = \frac{r_{max,K} \cdot C_K + r_{max,L} \cdot C_L}{C_K + C_L}$.

EXAMPLE:

$r_{min,K}$ = 0,67 & $r_{max,K}$ = 2,00 and
$r_{min,L}$ = 0,71 & $r_{max,L}$ = 1,67 with
C_K = 2 mSv and C_L = 8 mSv.

This results in $r_{min,w} = \frac{0{,}67 \cdot 2\,\text{mSv} + 0{,}71 \cdot 8\,\text{mSv}}{10\,\text{mSv}} = 0{,}70$ and $r_{max,w} = \frac{2{,}0 \cdot 2\,\text{mSv} + 1{,}67 \cdot 8\,\text{mSv}}{10\,\text{mSv}} = 1{,}74$.

In that case the requirement of 12.1 is considered to be met.

13 Environmental performance requirements and tests

13.1 General

13.1.1 General requirement

The influence quantities dealt with in this clause are of type F and/or type S. Therefore, two different requirements are valid for each influence quantity: One as if it was of type F (the range of relative response, r, is limited) and the other as if it was of type S (the deviation, D, is limited).

For the reader, only requirements according to a usual indoor use are given (varying temperature and light exposure, for example heating behind a large window due to sunlight).

13.1.2 General method of test

As the tests described in this clause are performed using rather low doses such as $7 \cdot H_{low}$ the consideration of the natural background radiation is of special importance, see 5.2.4.

Three different situations may occur:

a) In case it is not clear whether the influence quantity acts as type F or as type S, the conventional ~~true~~ quantity value of the dose equivalent shall be $7 \cdot H_{low}$ if not stated

otherwise in the respective subclause. For every group, n (≥ 6) dosemeters shall be irradiated. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the dosemeters may be irradiated at a higher dose equivalent if it is assumed that this is a type F influence quantity. Otherwise, the number of dosemeters shall be increased, see Clause A.1.

NOTE As stated above, also the influence quantities that may be of type S are limited by a maximum permitted value for the variation of the response. As the conventional ~~true~~ quantity value of the dose equivalent is $7 \cdot H_{low}$, a change of the response by 10 % is equivalent to a deviation of $0{,}7 \cdot H_{low}$. Therefore, by this method of test, it is simultaneously ensured, that the deviation and the variation of the response from unity are not larger than the figures given above: $0{,}7 \cdot H_{low}$ and 10 %, respectively.

b) In case the influence quantity acts as type F, the conventional ~~true~~ quantity value of the dose equivalent shall be at least $10 \cdot H_{low}$ if not stated otherwise in the respective subclause. For every group, n (≥ 6) dosemeters shall be irradiated. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the dosemeters may be irradiated at a higher dose equivalent and / or the number of dosemeters shall be increased, see Clause A.1.

c) In case the influence quantity acts as type S, the conventional ~~true~~ quantity value of the dose equivalent shall be $7 \cdot H_{low}$ if not stated otherwise in the respective subclause. For every group, n (≥ 6) dosemeters shall be irradiated. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the number of dosemeters shall be increased, Clause A.1.

13.2 Ambient temperature and relative humidity (dosemeter)

13.2.1 General

The influence quantity dealt with in 13.2 is assumed to be of type F or of type S.

13.2.2 Requirements

The relative response and the deviation due to a change of the ambient temperature and relative humidity within their rated ranges shall not exceed the values given in line 1 of Table 14.

13.2.3 Method of test

For this test, three groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the three groups after the irradiation:

Group 1: reference group: the temperature and the relative humidity shall be at standard test conditions, see Table 7.

Group 2: the dosemeters shall be exposed to the lower extreme value of the rated range of the temperature. The relative humidity does not have to be controlled.

Group 3: the dosemeters shall be exposed to the upper extreme value of the rated range of the temperature and the upper extreme value of the rated range of the relative humidity (not condensing).

The duration of exposure shall be one week. As shortly as possible, ~~that means as short as~~ but not shorter than allowed by the instructions of use, the dosemeters shall be read out.

For every group, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

13.2.4 Interpretation of the results

If, for every group, the inequality $r_{\text{min}} \leq \left(\frac{\overline{G_i}}{\overline{G_1}} \pm U_{\text{com}} \right) \leq r_{\text{max}}$ (for type F influence quantities) or the inequality $\left| \overline{G_i} - \overline{G_1} \pm U_{\text{com}} \right| \leq D_{\text{max}}$ (for type S influence quantities) is valid, then the requirements of 13.2.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 1 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.3 Light exposure (dosemeter)

13.3.1 General

The influence quantity dealt with in 13.3 is assumed to be of type F or of type S.

13.3.2 Requirements

The relative response and the deviation due to a change of the light exposure within its rated range shall not exceed the values given in line 2 of Table 14.

13.3.3 Method of test

For this test, two groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the two groups after the irradiation:

Group 1: reference group: the dosemeters shall be maintained at normal daylight in the shadow.

Group 2: the dosemeters shall be exposed to the maximum value within the rated range of light exposure for one week. During this test, the temperature shall be between 15 °C and 25 °C. A water cooling is recommended as the light source usually produces a lot of thermal energy.

To produce, for example, an effective cumulative integrated irradiance of 1 000 W/m^2 in the complete range of wavelengths at the test plane, use an apparatus which produces light whose spectrum corresponds to that of bright sunlight: at least 45 W/m^2 in the range of wavelengths between 300 nm and 400 nm and at least 630 W/m^2 in the range of wavelengths between 400 nm and 900 nm (values taken from the AM 1.5 spectrum in IEC 60904-3).

If 45 W/m^2 and 630 W/m^2 (in the respective ranges of wavelengths) cannot be attained the irradiance can be decreased by up to a factor of 2, however, the exposure time then has to be increased by the same factor.

NOTE A reference solar spectral irradiance distribution is given in IEC 60904-3.

For every group, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

13.3.4 Interpretation of the results

If the inequality $r_{min} \leq \left(\frac{\overline{G}_2}{\overline{G}_1} \pm U_{com} \right) \leq r_{max}$ (for type F influence quantities) or the inequality $\left| \overline{G}_2 - \overline{G}_1 \pm U_{com} \right| \leq D_{max}$ (for type S influence quantities) is valid, then the requirements of 13.3.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 2 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.4 Dose build-up, fading and self-irradiation~~, and response to natural radiation~~ (dosemeter)

13.4.1 General

The influence quantity dealt with in 13.4 (time) is assumed to be of type F and type S.

13.4.2 Requirements

The relative response and the deviation due to dose build up, fading and self-irradiation shall not exceed the values given in line 3 of Table 14.

~~The indicated value due to self-irradiation and natural radiation shall not differ by more than the lower limit of the measuring range from the conventional true value of the natural radiation during the maximal rated measurement time.~~

13.4.3 Method of test

For this test, ~~eight~~ three groups of dosemeters shall be used.

~~Groups 1 to 3 consisting of n ($\geq$ 6) dosemeters shall be exposed to a reference source to 7 times the lower limit of the measuring range, $7 \cdot H_{low}$.~~

~~Group 4 consisting of n ($\geq$ 25) dosemeters shall be exposed to the lower limit of the measuring range, H_{low}.~~

~~Groups 5 to 7 consisting of n ($\geq$ 6) dosemeters and group 8 consisting of n ($\geq$ 25) dosemeters shall not be exposed.~~

~~Further information regarding the method of test are given in 13.1.2.~~

~~Treatment of the eight groups after the irradiation:~~

~~Especially groups 4 and 8 shall be stored together at a known level of natural background dose rate.~~

~~Groups 1 and 5 shall be read out 1 h after the irradiation, if this is not in contradiction with the instruction manual. If so, the minimal time that is allowed by the instruction manual to be between irradiation and readout shall be taken.~~

~~Groups 2 and 6, reference groups, shall be read out one week after the irradiation.~~

~~Groups 3, 4, 7, and 8 shall be read out after the maximum rated measurement time t_{max} after the irradiation.~~

~~For groups 5 to 8 the mean indicated value~~ $\overline{G}_k$ ~~shall be determined (k = 5..8).~~

~~From every indicated value of groups 1 to 4 the mean indicated value of groups 5 to 8 shall be subtracted, respectively: $\{G_{j,1} - \overline{G}_5\}$, $\{G_{j,2} - \overline{G}_6\}$, $\{G_{j,3} - \overline{G}_7\}$, and $\{G_{j,4} - \overline{G}_8\}$. From these new groups prime, the mean values~~ $\overline{G}'_i$ ~~shall be determined (i = 1..4).~~

~~NOTE 1 This subtraction represents the determination of net doses.~~

~~NOTE 2 The subtraction $\{G_{j,t} - \overline{G}_k\}$ can be made before or after the dose calculation.~~

Groups 1 to 3 consisting of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2. The irradiations should be performed at different times so that all readings take place at the same time (in order to exclude possible effects due to reader instabilities during the test). If all irradiations are performed at the same time effects due to reader instabilities need to be corrected for.

Further information regarding the method of test is given in 13.1.2.

Treatment of the three groups after the irradiation:

Group 1 shall be read out 24 h (or as soon as possible) after the irradiation.

Group 2, reference group, shall be read out one week after the irradiation.

Group 3 shall be read out after the maximum rated measurement time t_{max} after the irradiation.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.4.4 Interpretation of the results

~~If for groups 1' to 3' the inequality~~ $r_{min} \leq \left(\frac{\overline{G}'_i}{\overline{G}'_2} \pm U_{com} \right) \leq r_{max}$ ~~(for type F influence quantities) or the inequality~~ $\left| \overline{G}'_i - \overline{G}'_2 \pm U_{com} \right| \leq D_{max}$ ~~(for type S influence quantities) is valid, and if for group 4' the inequality~~ $r_{min} \leq \left(\frac{7 \cdot \overline{G}'_4}{\overline{G}'_2} \pm U_{com} \right) \leq r_{max}$ ~~(for type F influence quantities) or the inequality~~ $\left| 7 \cdot \overline{G}'_4 - \overline{G}'_2 \pm U_{com} \right| \leq D_{max}$ ~~(for type S influence quantities) is valid, and if for group 8 the inequation~~ $-H_{low} \leq \overline{G}_8 \pm U_m - C_{nat} \leq +H_{low}$ ~~is valid, then the requirements of 13.4.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 3 of Table 13.~~

~~For C_{nat}, a value of 2 µSv/d multiplied by t_{max} can be assumed. If the inequation is not fulfilled, the conventional true dose equivalent of the natural radiation during the storage of groups 4 and 8 has to be taken for C_{nat}.~~

~~U_{com} and U_m are calculated according to Equation (A.5), Example 2, and Equation (A.3), respectively.~~

If for groups 1 to 3 the inequality $r_{\text{min}} \leq \left(\frac{\overline{G}_i}{\overline{G}_2} \pm U_{\text{com}} \right) \leq r_{\text{max}}$ (for type F influence quantities) or the inequality $\left| \overline{G}_i - \overline{G}_2 \pm U_{\text{com}} \right| \leq D_{\text{max}}$ (for type S influence quantities) is valid, then the requirements of 13.4.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 3 of Table 14.

U_{com} and U_{m} are calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively, and formula (A.3), respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.5 Sealing (dosemeter)

The manufacturer shall state the precautions to be taken to prevent the ingress of moisture, and describe the tests and results used to demonstrate the effectiveness of the sealing.

This requirement is essential for extremity dosemeters as they usually have to be disinfected using liquids.

13.6 Reader stability (reader)

13.6.1 General

The influence quantity dealt with in 13.6 (time) is assumed to be of type F or of type S.

13.6.2 Requirements

The relative response and the deviation due to reader stability shall not exceed the values given in line 5 of Table 14 over the maximum rated measurement time t_{max}.

13.6.3 Method of test

For this test, three groups of n (≥ 6) dosemeters shall be used.

Group 1 shall be irradiated at the beginning of the type test and read out one week later.

Group 2 shall be irradiated to the same dose as group 1 after half of the maximum rated measurement time $t_{\text{max}}/2$ and read out one week later.

Group 3 shall be irradiated to the same dose as groups 1 and 2 after the maximum rated measurement time t_{max} and read out one week later.

Further information regarding the method of test is given in 13.1.2.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.6.4 Interpretation of the results

If, for every group, the inequality $r_{\text{min}} \leq \left(\frac{\overline{G}_i}{\overline{G}_1} \pm U_{\text{com}} \right) \leq r_{\text{max}}$ (for type F influence quantities) or the inequality $\left| \overline{G}_i - \overline{G}_1 \pm U_{\text{com}} \right| \leq D_{\text{max}}$ (for type S influence quantities) is valid, then the requirements of 13.6.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 5 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.7 Ambient temperature (reader)

13.7.1 General

The influence quantity dealt with in 13.7 may be of type S or of type F.

13.7.2 Requirements

The relative response and the deviation due to a change of the temperature within its rated range shall not exceed the values given in line 6 of Table 14.

In case it can be made sure by physical reasons that ~~light~~ temperature does not have a significant effect on the indicated value then this test can be omitted.

13.7.3 Method of test

This test shall only be done in case a temperature range outside +15 °C and +25 °C is specified by the manufacturer.

For this test, two groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

~~Groups 1 and 2 shall be exposed to 7·H_{low}, see 13.1.2.~~

Treatment of the two groups after the irradiation:

Group 1, reference group: the temperature of the reader shall be at standard test conditions (see Table 7) and the dosemeters shall be read out.

Groups 2: the temperature of the reader shall be at least 4 h at the highest temperature within the rated range. At the end of at least 4 h, the readout of the dosemeters shall be performed holding the given temperature.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.7.4 Interpretation of the results

If the inequality $r_{min} \leq \left(\frac{\overline{G}_2}{\overline{G}_1} \pm U_{com} \right) \leq r_{max}$ (for type F influence quantities) or the inequality $\left| \overline{G}_2 - \overline{G}_1 \pm U_{com} \right| \leq D_{max}$ (for type S influence quantities) is valid, then the requirements of 13.7.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 6 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.8 Light exposure (reader)

13.8.1 General

The influence quantity dealt with in 13.8 is usually of type S, it may be of type F.

In case it can be made sure by physical reasons that light does not have a significant effect on the indicated value then this test can be omitted.

13.8.2 Requirements

The relative response and the deviation due to a change of the light exposure within its rated range shall not exceed the values given in line 7 of Table 14.

13.8.3 Method of test

For this test, two groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

~~Groups 1 and 2 shall be exposed to $7 \cdot H_{low}$, see 13.1.2.~~

Treatment of the two groups after the irradiation:

The dosemeters shall not (or as minimally as possible) be exposed to the additional light source.

Group 1, reference group: the reader shall not be exposed to any additional light than the usual daylight in shadow and the dosemeters shall be read out.

Group 2: the outside parts of the reader near the seal of the photomultiplier or other light sensitive devices of the reader shall be exposed to the extreme value of light exposure (for example by placing a lamp close to the surface of the reader) within the rated range and the dosemeters shall be read out. During this test, the temperature shall be between 15 °C and 25 °C. Water cooling is recommended as the light source usually produces a lot of thermal energy.

To produce for example an effective cumulative integrated irradiance of 1 000 W/m^2 in the complete range of wavelengths at the test plane, use a device or an lamp which produces light whose spectrum corresponds approximately to that of bright sunlight: at least 45 W/m^2 in the range of wavelengths between 300 nm and 400 nm and at least 630 W/m^2 in the range of wavelengths between 400 nm and 900 nm (values taken from the AM 1.5 spectrum in IEC 60904-3).

NOTE A reference solar spectral irradiance distribution is given in IEC 60904-3.

For every group, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

13.8.4 Interpretation of the results

If the inequality $r_{min} \leq \left(\frac{\overline{G_2}}{\overline{G_1}} \pm U_{com} \right) \leq r_{max}$ (for type F influence quantities) or the inequality $\left| \overline{G_2} - \overline{G_1} \pm U_{com} \right| \leq D_{max}$ (for type S influence quantities) is valid, then the requirements of 13.8.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 7 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.9 Primary power supply (reader)

13.9.1 General

The influence quantity dealt with in 13.9 is usually of type F, it may be of type S.

13.9.2 Requirements

The relative response and the deviation due to a change of the power supply voltage and frequency within its rated range shall not exceed the values given in line 8 of Table 14.

In addition, the coefficient of variation shall fulfil the requirements specified in 11.2.

13.9.3 Method of test

For this test, five groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the five groups after the irradiation:

The dosemeters shall be read out under the following conditions:

Group 1, reference group: nominal power supply voltage and frequency

Group 2: minimum voltage and minimum frequency within their rated ranges

Group 3: maximum voltage and minimum frequency within their rated ranges

Group 4: minimum voltage and maximum frequency within their rated ranges

Group 5: maximum voltage and maximum frequency within their rated ranges

For every group, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

13.9.4 Interpretation of the results

If, for every group, the inequality $r_{min} \leq \left(\frac{\overline{G_i}}{\overline{G_1}} \pm U_{com} \right) \leq r_{max}$ (for type F influence quantities) or the inequality $\left| \overline{G_i} - \overline{G_1} \pm U_{com} \right| \leq D_{max}$ (for type S influence quantities) is valid, then the requirements of 13.9.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 8 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

14 Electromagnetic performance requirements and tests (dosimetry system)

14.1 General

Special precautions shall be taken in the design of a dosimetry system to ensure proper operation in the presence of electromagnetic disturbances. Electromagnetic disturbance are mainly influence quantities of type S.

Tests shall be performed for all components of the dosimetry system containing electronic components. This is usually, at least, the case for readers but may also be the case for badges, e.g. in case of a direct ion storage (DIS) dosemeter.

14.2 Requirements

The absolute value of the deviation due to electromagnetic disturbances shall not exceed $0{,}7 \cdot H_{low}$ for every single influence quantity, see Table 15. Exception: The absolute value of the deviation may be larger than $0{,}7 \cdot H_{low}$ for one indicated value, if the dosimetry system delivers an error message assigning that this value is faulty. In addition, the dosimetry system shall not lose more than one indicated value, see 10.5.

For all influence quantities, the mandatory ranges are taken from IEC 61000-6-2.

The tests in lines 4, 5, and 7 of Table 15 need not to be done for readers for which the manufacturer declares that either the respective influence quantity does not affect the indicated value by more than $0{,}7 \cdot H_{low}$ during readout of dosemeters or the effect is recognized and accompanied by an error message (at most one, see above) or the effect is corrected for (for example by means of software). This declaration shall contain the necessary evidence. This evidence can be a physical reason why the device is not affected by the electromagnetic disturbance or why the electromagnetic disturbance is not present. This evidence has to be stated for each electromagnetic disturbance separately. One example is, that no mobile phones are allowed in the room of the reader.

The test in line 7 of Table 15 shall be conducted from at least two sides of the device under test and with both polarizations of the radio-frequency field for

- badges containing electronic components at 30 V/m with a frequency sweep and
- for all other parts of the dosimetry system containing electronic components such as the reader at 30 V/m with at least the frequencies stated in note e of Table 15; if that test leads to a failure then a test at 10 V/m shall be conducted from all six sides of the device under test.

14.3 Method of test

~~For this test, seven groups of n (≥ 10) dosemeters shall be exposed to a reference source with a dose equivalent of $7 \cdot H_{low}$.~~

~~Group 8 of n (≥ 37) dosemeters is only necessary in case that no declaration of the manufacturer is available, see above. It shall be exposed to a reference source with a dose equivalent of $7 \cdot H_{low}$ as well.~~

As the tests described in this clause are performed using rather low doses such as $7 \cdot H_{low}$ the consideration of the natural background radiation is of special importance, see 5.2.4.

For the test according to lines 1 to 6 of Table 15 seven groups of n (≥ 10) dosemeters and for the test according to line 7 of Table 15 one group of n (≥ 60) dosemeters shall be exposed to a reference source with a dose equivalent of $7 \cdot H_{low}$. For those influence quantities for which a declaration of the manufacturer is available, see 14.2, no dosemeters need to be irradiated.

Group 1, reference group: no electromagnetic influences shall be present. To ensure this, appropriate filters, shieldings and so on shall be applied.

Groups 2, 6 and 8: in case the dosemeters contain any electric parts that may be sensitive to electromagnetic disturbances (for example a DIS dosemeter), the dosemeters shall be exposed to the influence quantities according to lines 1, 5 and 7 of Table 15 prior to their readout. The radio frequency radiation shall be applied ~~in frequency steps not larger than 10 %~~ with the frequencies stated in footnote e to Table 15.

Group 1 shall be read out without any electromagnetic influences.

Groups 2 to 8 shall be read out while the different electromagnetic influences are applied to the reader in accordance with the standards of the IEC 61000-4 series as given in Table 15. Each electromagnetic influence shall be applied for the duration of the readout of one dosemeter. If possible, the output of the reader (for example glow curve) shall be observed. Without error message, no abnormal characteristics (for example spikes in a glow curve that cause non-negligible doses) shall occur.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined. In case any indicated values were marked by the dosimetry system as faulty, these values shall be excluded from the determination of $\overline{G}_i$ and s_i.

14.4 Interpretation of the results

If, for every group, the inequality $\left|\overline{G}_i - \overline{G}_1 \pm U_{\text{com}}\right| \leq 0{,}7 \cdot H_{\text{low}}$ is valid and if for the tests with criterion A no single indicated value is lost, and if for the tests with criterion B or C at most one indicated value per influence quantity is lost, then the requirement of 14.2 is considered to be met.

U_{com} is calculated according to formula (A.5). This calculation presumes that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

NOTE The maximum is built over the two possibilities $\left|\overline{G}_i - \overline{G}_1 + U_{\text{m}}\right|$ and $\left|\overline{G}_i - \overline{G}_1 - U_{\text{m}}\right|$.

15 Mechanical performance requirements and tests

15.1 General requirement

Mechanical disturbances are mainly influence quantities of type S, they may be of type F. For the sake of simplification, the mathematical treatment is done as if all influence quantities were of type S.

The absolute value of the deviation due to mechanical disturbances shall not exceed $0{,}7 \cdot H_{\text{low}}$ for every single influence quantity (see Table 16). Exception: The absolute value of the deviation may be larger than $0{,}7 \cdot H_{\text{low}}$ for one indicated value, if the dosimetry system delivers an error message assigning that a specific indicated value is faulty.

It is not allowed to have more than one indicated value lost or accompanied by an error message due to any occurrence of abnormal operation, see 10.5.

15.2 Drop (dosemeter)

15.2.1 Requirements

A dosemeter shall be able to withstand drops from a height of 1,0 m onto a flat and hard surface made of concrete or steel (IEC 60068-2-31) without the deviation exceeding $\pm\ 0{,}7 \cdot H_{low}$ after the drop. These tests shall be on each face of the dosemeter.

The dosemeter shall not be damaged, neither on the inside (for example loosening of filter material) nor on the outside.

15.2.2 Method of test

As the tests described in this clause are performed using rather low doses such as $7 \cdot H_{low}$ the consideration of the natural background radiation is of special importance, see 5.2.4.

For these tests two groups of n (≥ 6) dosemeters shall be exposed to a reference source with a dose equivalent of $7 \cdot H_{low}$. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the dosemeters may be irradiated at a higher dose equivalent in case the influence quantity acts as a type F influence quantity. Otherwise, the number of dosemeters should be increased, see Clause A.1.

Group 1: reference group.

Group 2: each of the dosemeters shall be subjected to a test consisting of drops on each of the 6 faces of the dosemeter.

The dosemeters shall be inspected and the physical condition documented, for example whether the filter materials are fixed and in position.

After all the tests, the dosemeters shall be read out and the indicated values be determined.

For groups 1 and 2, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined. In case any indicated values were marked by the dosimetry system as faulty, these values shall be excluded from the determination of $\overline{G}_i$ and s_i.

NOTE As stated above, also the influence quantities that may be of type F are limited by a maximum permitted value for the deviation: $\pm\ 0{,}7 \cdot H_{low}$. As the conventional ~~true~~ quantity value of the dose equivalent is $7 \cdot H_{low}$, a deviation of $\pm\ 0{,}7 \cdot H_{low}$ is equivalent to a change of the response of ± 10 %. Therefore, by this method of test, it is simultaneously ensured, that the deviation and the variation of the response from unity are not larger than the figures given above ($\pm\ 0{,}7 \cdot H_{low}$ and ± 10 %, respectively).

15.2.3 Interpretation of the results

If for the two groups the inequality $\left|\overline{G}_2 - \overline{G}_1 \pm U_{com}\right| \leq 0{,}7 \cdot H_{low}$ is valid, then the requirement of 15.2.1 is considered to be met.

U_{com} is calculated according to formula (A.5). This calculation presumes that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

16 Documentation

16.1 Type test report

At the request of the customer, the manufacturer shall make available the report on the type tests performed according to the requirements of this document.

16.2 Certificate issued by the laboratory performing the type test

A certificate shall be issued to each dosimetry system, providing at least the following information:

Dosimetry system in general:

- manufacturer's name or registered trade mark (if the system is manufactured as a whole);
- type of dosimetry system and principle of operation;
- statement that the equipment is tested according to this document and that the requirements are fulfilled;
- name of the software of the dosimetry system and identification number (see 10.3);
- if the evaluation algorithm is not additive, a comment according to Note 3 of 12.1.

Reader:

- manufacturer's name or registered trade mark;
- type of the reader and serial number of the reader under test.

Dosemeter:

- manufacturer's name or registered trade mark;
- type of dosemeter and serial numbers of the dosemeters under test;
- type of detector or detectors;
- types of radiation the dosemeter is intended to measure.
- ~~method to prevent ingress of moisture.~~

Dosimetric characteristics:

- measuring quantity;
- measuring range and variation of the response due to non-linearity;
- coefficient of variation depending on the dose equivalent;
- maximum rated measurement time;
- relative response as a function of radiation energy and angle of incidence (for both beta and photon radiation);
- rated ranges of all other influence quantities and the corresponding variation of the response or deviation (see 7.2 to 7.6, an example is given in 7.7).

Table 6 – Symbols

Symbol	Meaning	Unit
α	Angle of radiation incidence	Degrees
α_{max}	Maximum value of the rated range of the angle of radiation incidence	Degrees
b	Number of signals of one dosemeter that are used to evaluate the indicated dose value	—
C	Conventional ~~true~~ quantity dose value	Sv
C_i	Conventional ~~true~~ quantity dose value of irradiation group i	Sv
C_K	Conventional ~~true~~ quantity value of (delivered) dose equivalent for irradiation condition K	Sv
C_L	Conventional ~~true~~ quantity value of (delivered) dose equivalent for irradiation condition L	Sv
~~C_{nat}~~	~~Conventional true value of dose equivalent from natural radiation during the storage for the maximum rated measurement time, t_{max}~~	~~Sv~~
C_r	Conventional ~~true~~ quantity value of (delivered) dose equivalent under reference conditions: that means, all influence quantities have their reference value, except the value of the dose equivalent is different from its reference condition: $C_r \neq C_{r,0}$	Sv
$C_{r,0}$	As C_r but only for reference dose equivalent, see Table ~~2~~ 7, line 1	Sv
ΔG	Change in indication caused by subsequent and mixed exposure, see 11.9	Sv
d	Depth in ICRU 4-element or soft tissue. Recommended depths are 10 mm, 3 mm, and 0,07 mm	m
D	Deviation	Sv
D_{EMC}	Deviation due to electromagnetic disturbances	Sv
D_{max}	Maximum permitted variation of deviation due to an influence quantity	Sv
D_{mech}	Deviation due to mechanical disturbances	Sv
D_p	Deviation due to influence quantity no. p of type S; p = 1..l	Sv
E_{beta}	Beta energy	keV or MeV
E_{ph}	Photon energy	keV or MeV
$f(S_1,\ldots S_b) = f(S_g)$	Function representing the evaluation algorithm inside the dosimetry system to evaluate the indicated value	Sv
g	Designator for a specific signal delivered from one dosemeter; g = 1..b	—
G	Indicated value	Sv
$\overline{G}_i$	Mean indicated value of group i	Sv
$\overline{G}'_i$	Mean indicated value of group i prime (background indications subtracted)	Sv
G_j	Indicated value of the j-th dosemeter of several dosemeters irradiated equally; j = 1..n	Sv
$G_{j,i}$	Indicated value of the j-th dosemeter of group i	Sv
G_K	Indicated value due to a single irradiation with C_K	Sv
G_{K+L}	Indicated value due to a combined irradiation with C_K + C_L	Sv
G_L	Indicated value due to a single irradiation with C_L	Sv
G_r	Indicated value of a dosemeter irradiated with C_r	Sv
$G_{r,0}$	Indicated value of a dosemeter irradiated with $C_{r,0}$	Sv
$h_{pK}(d;R,\alpha)$	Conversion coefficient from air kerma to the personal dose equivalent at a depth d for the radiation series R	Sv
$h'_K(d;R,\alpha)$	Conversion coefficient from air kerma to the directional dose equivalent at a depth d for the radiation series R	Sv
H	Synonym for dose equivalent, may be $H_p(10)$, $H_p(0,07)$ or $H^*(10)$	Sv
H_{low}	Lower dose limit of the range of measurement	Sv
H_{up}	Upper dose limit of the range of measurement	Sv

Symbol	Meaning	Unit
$H^*(10)$	Ambient dose equivalent at a depth 10 mm	Sv
$H^*(d)$	Ambient dose equivalent at a depth d	Sv
$H_p(0,07)$	Personal dose equivalent at a depth 0,07 mm	Sv
$H_p(3)$	Personal dose equivalent at a depth 3 mm	Sv
$H_p(10)$	Personal dose equivalent at a depth 10 mm	Sv
$H_p(d)$	Personal dose equivalent at a depth d	Sv
i	Designator for a group subjected to a specific influence quantity	—
j	Designator for a specific dosemeter out of n dosemeters irradiated equally	—
k	Coverage factor	—
K	Symbol of radiation condition K, e. g. 3 mSv, N-80 and 60°	—
l	Number of influence quantities of type S	—
L	Symbol of radiation condition L, e. g. 4 mSv, S-Co and 0°	—
m	Number of influence quantities of type F	—
M	Measured value	Sv
n	Number of dosemeters in one group that are equally irradiated	—
N	Pointer to the table entry containing the signals (N's row)	—
N_0	(Reference) calibration ~~factor~~ coefficient	—
N_{max}	Number of rows in the table containing the signals	—
p	Designator for a specific influence quantity of type S out of l type S influence quantities	—
q	Designator for a specific influence quantity of type F out of m type F influence quantities	—
r	Relative response	—
$r_{E,\alpha}$	Relative response due to energy and angle of incidence	—
r_{env}	Relative response due to environmental influences	—
r_{max}	Maximal permitted value of the relative response due to an influence quantity	—
$r_{max,w}$	Maximal permitted value of the relative response due to an influence quantity for a mixed irradiation	—
r_{min}	Minimal permitted value of the relative response due to an influence quantity	—
$r_{min,w}$	Minimal permitted value of the relative response due to an influence quantity for a mixed irradiation	—
r_n	Relative response due to non-linearity	—
r_q	Relative response due to influence quantity no. q of type F; q = 1..m	—
R	Symbol of radiation series R, for example, N series or S series	—
R	Response	—
R_0	Reference response	—
R_n	Response under reference conditions, except the value of the dose equivalent is different from reference conditions	—
s	Standard deviation	As quantity
s_i	Standard deviation of group i	As quantity
S	Signal of a detector; from one detector more than one signal can be derived	Depending
S_g	Signal number g of a dosemeter; g = 1..b	Depending
$S_{g,K}$	Signal number g due to the radiation quality K	Depending
$S_{g,L}$	Signal number g due to the radiation quality L	Depending
t_{max}	Maximum rated measurement time	Month
t_{n-1}	Students t-factor for n measurements	—

Symbol	Meaning	Unit
U	Expanded uncertainty	As quantity
$U_{C,\mathrm{com}}$	Expanded uncertainty of a combined quantity of conventional ~~true~~ 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
$U_{C,\mathrm{rel}}$	Relative expanded uncertainty of the conventional ~~true~~ quantity value	—
U_{com}	Expanded uncertainty of a combined quantity. This is equivalent to the half-width of the confidence interval about the combined quantity at a confidence level of 95 %. See Annex A, formula (A.5)~~, Example 2~~	As quantity
U_{m}	Expanded uncertainty of a mean value. This is equivalent to the half-width of the confidence interval about a mean at a confidence level of 95 %	As quantity
U_{rel}	Relative expanded uncertainty	—
V	Coefficient of variation	As quantity

Table 7 – Reference conditions and standard test conditions

Quantity to be measured; influence quantity	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Reference dose equivalent $C_{r,0}$ for $H_p(10)$, $H^*(10)$, $H_p(3)$, $H'(3)$, $H_p(0,07)$ and $H'(0,07)$	3 mSv 10 mSv	1 mSv to 10 mSv 3 mSv to 30 mSv
Photon radiation energy for $H_p(10)$, $H^*(10)$, $H_p(3)$, $H'(3)$, $H_p(0,07)$, and $H'(0,07)$	S-Cs (ISO 4037) [a]	S-Cs (ISO 4037) [a]
Beta radiation energy for $H_p(3)$, $H'(3)$, $H_p(0,07)$, and $H'(0,07)$	^{90}Sr/^{90}Y (ISO 6980) [a,b]	^{90}Sr/^{90}Y (ISO 6980) [a,b]
Reference point of a dosemeter	See 3.34	See 3.34
Reference orientation	See 3.33	See 3.33
Angle of incidence of radiation	Reference direction given by the manufacturer	Reference direction ± 2°
Ambient temperature	20 °C	15 °C to 25 °C [c]
Relative humidity	65 %	50 % to 75 % [c]
Atmospheric pressure	101,3 kPa	86,0 kPa to 106,6 kPa [c]
Power supply voltage	Nominal power supply voltage	Nominal power supply voltage ± 1 %
Frequency	Nominal frequency	Nominal frequency ± 1 %
AC power supply waveform	Sinusoidal	Sinusoidal with total harmonic distortion less than 5 %
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the induction due to the earth's magnetic field
Dosemeter controls	Set up for normal operation	Set up for normal operation
Radiation background	Ambient dose equivalent rate of 0,1 μSv/h or less if practical	Less than ambient dose equivalent rate of 0,25 μSv/h
Contamination by radioactive elements	Negligible	Negligible

[a] Obey the third paragraph in 11.1 regarding dosimetry systems intended to measure both photon and beta radiation.

[b] For beta dosemeters, alternatively a photon radiation quality may be chosen as reference radiation quality.

[c] The actual values of theses quantities at the time of test shall be stated. The conventional ~~true~~ quantity value of the dose equivalent shall be corrected for the deviation from reference conditions. A lower limit of pressure of
70 kPa may be permitted at high altitudes.

Table 8 – Performance requirements for $H_p(10)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	$H < 0{,}1$ mSv $0{,}1$ mSv $\leq H < 1{,}1$ mSv $H \geq 1{,}1$ mSv	15 % $(16 - H / 0{,}1\text{ mSv})$ % 5 %	11.2
7	Relative response due to non-linearity	$0{,}1\text{ mSv} \leq H \leq 1\text{ Sv}$	~~– 9 % to +11 %~~ – 13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum ~~10~~ 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	80 keV to 1,25 MeV and 0° to ± 60° ~~from reference direction~~	~~For 12 keV $\leq E_{ph} <$ 33 keV: $r_{min} = 0{,}67$ to $r_{max} = 2{,}00$ and for 33 keV $\leq E_{ph} <$ 65 keV: $r_{min} = 0{,}69$ to $r_{max} = 1{,}82$ and for $E_{ph} \geq$ 65 keV:~~ $r_{min} = 0{,}71$ to $r_{max} = 1{,}67$	11.5.1
10	Relative response due to mean beta radiation energy	0,8 MeV	Indicated value maximal 10 % of $H_p(0{,}07)$ dose equivalent	11.5.2
11	As in lines 9 and 10 but new reference direction opposite to that one used	See lines 9 and 10, if no statement by the manufacturer	See lines 9 and 10, if no statement by the manufacturer	8.4 ~~f~~e)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from ~~60° to 120°~~ α_{max} to 180°– α_{max}	Indication less than ~~1,5~~ 2 times of indication due to irradiation free in air from the front	11.8
13	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
14	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
15	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
16	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	$\pm 0{,}7 \cdot H_{low}$ at a dose of $H = 7\ H_{low}$	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in [0{,}6\ ..\ 1{,}4]$ ➔ $r \in [1/1{,}4\ ..\ 1/0{,}6] = [0{,}71\ ..\ 1{,}67]$				

Table 9 – Performance requirements for $H_p(3)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	~~$H < 0{,}1$ mSv~~ ~~0,1 mSv ≤ H < 1,1 mSv~~ ~~$H \geq 1{,}1$ mSv~~ $H < 0{,}3$ mSv 0,3 mSv ≤ H < 3,3 mSv $H \geq 3{,}3$ mSv	15 % (16 – H / ~~0,1~~ 0,3 mSv) % 5 %	11.2
7	Relative response due to non-linearity	~~0,1~~ 0,3 mSv ≤ H ≤ 1 Sv	~~–9 % to +11 %~~ –13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum ~~10~~ 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	30 keV to ~~250 keV~~ 1,25 MeV and 0° to ± 60° ~~from reference direction~~	r_{min} = 0,71 to r_{max} = 1,67	11.6.1
10	Only if the dosemeter is specified for beta radiation: Relative response, r, due to mean beta radiation energy and angle of incidence	A: 0,8 MeV and 0° to ± 60° ~~from reference direction~~ B: 0,24 MeV	A: r_{min} = 0,71 to r_{max} = 1,67 B: Indicated value maximal 10 % of $H_p(0{,}07)$ dose equivalent	11.6.2
11	As in lines 9 and 10 but new reference direction opposite to that one used	See lines 9 and 10, if no statement by the manufacturer	See lines 9 and 10, if no statement by the manufacturer	8.4 ~~f~~e)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from ~~60° to 120°~~ α_{max} to 180°– α_{max}	Indication less than 2 times of indication due to irradiation free in air from the front	11.8
13	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
14	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
15	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
16	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7·H_{low} at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in$ [0,6 .. 1,4] ➔ $r \in$ [1/1,4 .. 1/0,6] = [0,71 .. 1,67]				

Table 10 – Performance requirements for $H_p(0,07)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	$H < 1$ mSv 1 mSv $\leq H <$ 11 mSv $H \geq$ 11 mSv	15 % (16 – H / 1 mSv) % 5 %	11.2
7	Relative response due to non-linearity	1 mSv $\leq H \leq$ 3 Sv	~~–9~~13 % to +~~11~~18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum ~~10~~ 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	30 keV to ~~250~~ keV and 0° to ~~±~~ 60° ~~from reference direction~~	~~For 8 keV $\leq E_{ph} <$ 20 keV: $r_{min} = 0,67$ to $r_{max} = 2,00$ and for 20 keV $\leq E_{ph} <$ 33 keV: $r_{min} = 0,69$ to $r_{max} = 1,82$ and for $E_{ph} \geq$ 33 keV: 0,71 to 1,67~~ r_{min} = 0,71 to r_{max} = 1,67	11.7.1
10	Only if the dosemeter is specified for beta radiation: Relative response due to mean beta radiation energy and angle of incidence	0,24 MeV to 0,8 MeV and 0° to ± 60° for extremity dosemeters and 0,8 MeV and 0° to ± 45° for whole body dosemeters	~~For 0,06 MeV $\leq E_{beta} <$ 0,2 MeV: $r_{min} = 0,67$ to $r_{max} = 2,00$ and for 0,2 MeV $\leq E_{beta} <$ 0,7 MeV: $r_{min} = 0,69$ to $r_{max} = 1,82$ and for $E_{beta} \geq$ 0,7 MeV: 0,71 to 0,67 For whole body dosemeters: If not met, line 13 applies~~ r_{min} = 0,71 to r_{max} = 1,67 For whole body dosemeters: If not met, line 13 applies	11.7.2
11	As in lines 9 and 10 but new reference direction opposite to that one used	See lines 9 and 10, if no statement by the manufacturer	See lines 9 and 10, if no statement by the manufacturer	8.4 ~~f~~e)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from ~~60° to 120°~~ α_{max} to 180°– α_{max}	Indication less than 2 times of indication due to irradiation free in air from the front	11.8
13	For whole body dosemeters: Indication of the presence of beta dose	0,8 MeV at 0° angle of incidence	r_{min} = 0,71 to r_{max} = 1,67	11.9
14	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
15	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
16	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14

17	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7·H_{low} at a dose of H = 7 H_{low}	15

Table 11 – Performance requirements for H*(10) dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	~~H < 0,1 mSv~~ ~~0,1 mSv ≤ H < 0,5 mSv~~ ~~0,5 mSv ≤ H 20 mSv~~ ~~H > 20 mSv~~ H < 0,1 mSv 0,1 mSv ≤ H < 1,1 mSv H ≥ 1,1 mSv	~~15 %~~ ~~(18 – 3·H/0,1 mSv) %~~ ~~3 %~~ ~~5 %~~ 15 % (16 – H / 0,1 mSv) % 5 %	11.2
7	Relative response due to non-linearity	~~0,1 mSv ≤ H < 0,5 mSv~~ ~~0,5 mSv ≤ H ≤ 20 mSv~~ ~~20 mSv < H ≤ 1 Sv~~ 0,1 mSv ≤ H ≤ 1 Sv	~~For H < 0,1 mSv and above:~~ ~~–9 % to +11 %~~ ~~± 5 %~~ ~~–9 % to +11 % and for H > 1 Sv~~ –13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: 10·H_{up}, however at maximum ~~10~~ 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	80 keV to 1,25 MeV and 0° to ~~±75~~ 60° and 180° to (180°~~±75~~ 60°) and for environmental dosemeters from ~~±75~~ 60° to ~~±105° from reference direction~~ 120°	r_{min} = 0,71 to r_{max} = 1,67 and r_{min} = 0,67 to r_{max} = 2,00	11.5.1
10	Relative response due to mean beta radiation energy	0,8 MeV	Indicated value maximal 10 % of $H_p(0,07)$ dose equivalent	11.5.2
11	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
12	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
13	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
14	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7·H_{low} at a dose of H = 7 H_{low}	15

NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in [0,6 .. 1,4]$ ➔ $r \in [1/1,4 .. 1/0,6] = [0,71 .. 1,67]$

Table 12 – Performance requirements for $H'(3)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	$H < 0,3$ mSv $0,3$ mSv $\leq H < 3,3$ mSv $H \geq 3,3$ mSv	15 % (16 – H / 0,3 mSv) % 5 %	11.2
7	Relative response due to non-linearity	$0,3$ mSv $\leq H \leq 1$ Sv	–13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	30 keV to 1,25 MeV and 0° to ± 60° and 180° to (180°± 60°) and for environmental dosemeters from ± 60° to ± 120°	r_{min} = 0,71 to r_{max} = 1,67 and r_{min} = 0,67 to r_{max} = 2,00	11.6.1
10	Only if the dosemeter is specified for beta radiation: Relative response due to mean beta radiation energy and angle of incidence	A: 0,8 MeV and 0° to ± 60° B: 0,24 MeV	A: r_{min} = 0,71 to r_{max} = 1,67 B: Indicated value maximal 10 % of $H_p(0,07)$ dose equivalent	11.6.2
11	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
12	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
13	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
14	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7·H_{low} at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in [0,6 .. 1,4]$ ➔ $r \in [1/1,4 .. 1/0,6] = [0,71 .. 1,67]$				

Table 13 – Performance requirements for $H'(0,07)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	~~$H < 0,1$ mSv~~ ~~$0,1$ mSv $\leq H < 0,5$ mSv~~ ~~$0,5$ mSv $\leq H \leq 20$ mSv~~ ~~$H > 20$ mSv~~ $H < 1$ mSv 1 mSv $\leq H <$ 11 mSv $H \geq$ 11 mSv	~~15 %~~ ~~(18 – 3·H/0,1 mSv) %~~ ~~3 %~~ ~~5 %~~ 15 % (16 – H / 1 mSv) % 5 %	11.2
7	Relative response due to non-linearity	~~0,1 mSv $\leq H < 0,5$ mSv~~ ~~0,5 mSv $\leq H \leq 20$ mSv~~ ~~20 mSv $< H \leq 1$ Sv~~ 1 mSv $\leq H \leq$ 3 Sv	~~For $H < 0,1$ mSv and above:~~ ~~–9 % to +11 %~~ ~~± 5 %~~ ~~–9 % to +11 % and for $H > 1$ Sv~~ –13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: 10·H_{up}, however at maximum ~~10~~ 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	~~80 keV to 1,25 MeV and 0° to ± 75° and 180° to (180°± 75°) and from ± 75° to ± 105° from reference direction~~ 30 keV to 1,25 MeV and 0° to ± 60° and 180° to (180°± 60°) and for environmental dosemeters from ± 60° to ± 120°	r_{min} = 0,71 to r_{max} = 1,67 and r_{min} = 0,67 to r_{max} = 2,00	11.7.1
10	Only if the dosemeter is specified for beta radiation: Relative response due to mean beta radiation energy and angle of incidence	~~0,2~~ 0,24 MeV to 0,8 MeV and 0° to ± 60° ~~from reference direction~~	r_{min} = 0,71 to r_{max} = 1,67	11.7.2
11	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
12	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
13	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14

14	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	$\pm$ 0,7·H_{low} at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors (1/r), for example: $\pm$ 40 % for 1/r $\in$ [0,6 .. 1,4] ➔ r $\in$ [1/1,4 .. 1/0,6] = [0,71 .. 1,67]				

Table 14 – Environmental performance requirements for dosemeters and readers

Line	Characteristic under test	Mandatory range of influence quantity	Maximum permitted variation of relative response [a] and deviation, D, [b] for the rated range	Clause/ Sub-clause
1	Relative response and deviation due to ambient temperature and relative humidity (dosemeter)	• Personal dosemeters: –10 °C to +40 °C • Environmental dosemeters: –20 °C to +50 °C and 10 % to 90 % relative humidity, not condensing	Type F: r_{min} = 0,83; r_{max} = 1,25 Type S: D_{max} = ~~1,1~~ 1,4 H_{low} at a dose of H = ~~11~~ 7 H_{low}	13.2
2	Relative response and deviation due to light exposure (dosemeter)	0 W/m^2 to 1 000 W/m^2 (spectrum corresponding to bright sunlight)	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low}	13.3
3	Dose build-up, fading~~,~~ and self-irradiation ~~and response to natural radiation~~ (dosemeter)	Maximum rated measurement time: t_{max} ≥ 1 month	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of Table 8 to Table 13	13.4
4	Sealing (dosemeter)	Ingress shall be prevented	Precautions to be stated	13.5
5	Relative response and deviation due to reader stability (reader)	Stability over t_{max}	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low}	13.6
6	Relative response and deviation due to ambient temperature (reader)	+15 °C to +25 °C for at least 4 h but long enough to ensure temperature equilibrium with the environment.	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of Table 8 to Table 13	13.7
7	Relative response and deviation due to light exposure (reader)	0 W/m^2 to 1 000 W/m^2 (spectrum corresponding to bright sunlight)	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of Table 8 to Table 13	13.8
8	Relative response and deviation due to a change in the primary power supply (reader)	Power supply voltage: –15 % to +10 % from nominal value (for example 110 V or 230 V) Frequency: –2 % to +2 % from nominal value (for example 50 Hz or 60 Hz)	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of	13.9

			Table 8 to Table 13	

[a] Valid in case the influence quantity is assumed to be of type F.

[b] Valid in case the influence quantity is assumed to be of type S.

Table 15 – Electromagnetic disturbance performance requirements for dosimetry systems according to Clause 14

Line	Influence quantity	Mandatory range of influence quantity	Criterion[a]	Test according to	Maximum permitted deviation, D, for the rated range at a dose of $H = 7\ H_{low}$
1	Electrostatic discharge	~~0~~ 2 kV to ± 8 kV air discharge ~~0~~ 2 kV to ± 4 kV contact discharge	B	IEC 61000-4-2	± 0,7 H_{low}
2	Conducted disturbances: fast transients	~~0 kV to~~ ± 2 kV (a.c. and d.c.[b] power ports) ~~0 kV to~~ ± 1 kV (signal ports) [b] ~~0 kV to~~ ± 1 kV (functional earth ports) 5/50 ns (t_r/t_h) 5 kHz repetition frequency	B	IEC 61000-4-4	± 0,7 H_{low}
3	Conducted disturbances: surges	0,5 kV to ± 2 kV (a.c. power ports, line-to-earth) 0,5 kV to ± 1 kV (a.c. power ports, line-to-line) 0,5 kV to ± 0,5 kV (d.c. power ports) 0,5 kV to ± 1 kV (signal ports, line-to-earth) [c] 1,2/50 (8/20) µs (t_r/t_h)	B	IEC 61000-4-5	± 0,7 H_{low}
4	Conducted disturbances: radio-frequencies common mode	150 kHz to 80 MHz ~~0 V to~~ 10 V (rms, unmodulated) 80 % AM (1 kHz) (signal ports, a.c. power ports and functional earth ports)	A	IEC 61000-4-6	± 0,7 H_{low}
5	Power-frequency magnetic field	50 Hz, 60 Hz 30 A/m	A	IEC 61000-4-8	± 0,7 H_{low}
6	Conducted disturbances: Voltage dips Voltage interruptions	100 % reduction for 1 period (20 ms at 50 Hz) 30 % reduction for 500 ms 60 % reduction for 200 ms 100 % reduction for 5 000 ms	B C C C	IEC 61000-4-11	± 0,7 H_{low}
7	Radio-frequency amplitude modulated electromagnetic field	~~80 MHz to 2 400 MHz:~~ ~~0 V/m to 30 V/m (rms, unmodulated)~~ ~~80 % AM (1 kHz)~~ 80 MHz to 2,4 GHz: 30 V/m [d] (rms, unmodulated) 80 % AM (1 kHz) impinging to at least two sides of the device under test and with both polarities of the radio-frequency field	A	IEC 61000-4-3 ~~Frequency steps not larger than 10 % [d]~~ For badges: test at 30 V/m with a frequency sweep; For all other parts of the dosimetry system containing electronic components such as the reader: test at 30 V/m with at least the frequencies stated below [e]; if that test leads to a failure then test at 10 V/m from all six sides.	± 0,7 H_{low}

Line	Influence quantity	Mandatory range of influence quantity	Criterion[a]	Test according to	Maximum permitted deviation, D, for the rated range at a dose of $H = 7\ H_{low}$

[a] A: Device works properly during and after the test;
B: Device works properly after the test;
C: Device may be shut down during the test but it shall be possible to switch it on after the test;
For details, see IEC 61000-6-2.

[b] Only if cables above 3 m are allowed by the manufacturer.

[c] Only if cables above 30 m are allowed by the manufacturer.

~~[d] This results in 37 different frequencies (and thus dosemeters).~~

[d] 30 V/m is used as with this the number of orientations of the device under test can be reduced.

[e] Frequencies for the Radio-frequency test:
98 / 202 / 434 / 550 / 710 / 873 / 903 / 915 / 947 / 1 472 / 1 800 / 1 890 / 2 035 / 2 150 / 2 450 MHz.

Table 16 – Mechanical disturbances performance requirements for dosemeters

Line	Influence quantity	Mandatory range of influence quantity	Maximum permitted deviation, D, for the rated range at a dose of $H = 7\ H_{low}$	Subclause
1	Drop on surface (dosemeter)	1,0 m onto concrete surface (IEC 60068-2-31)	$\pm$ 0,7 H_{low}	15.2

Table 17 – List of abbreviations

Abbreviation	Meaning
CRC	cyclic redundancy check
DIS	direct ion storage
TLD	thermoluminescence detector
WLAN	wireless local area network

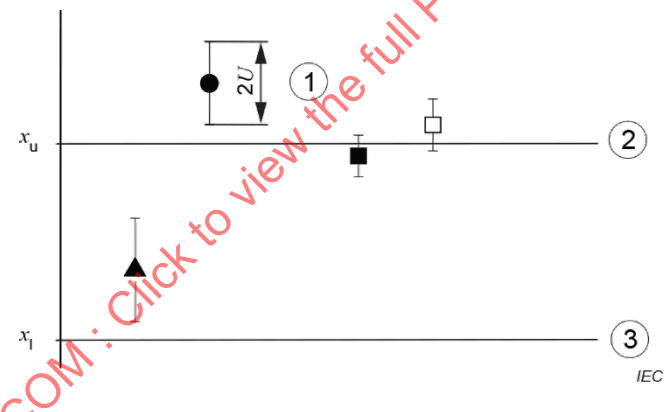
Annex A
(normative)

Confidence limits

A.1 General

If the magnitude of the random uncertainty of an indicated value is a significant fraction of the permitted tolerances of this indicated value, the random uncertainty shall be considered by performing more than one measurement (see 5.2.1). The number of measurements or the sample size shall be chosen in such a way that the confidence interval obtained for each mean, $\overline{x}$, for a confidence level of 95 % (that is the expanded uncertainty of the indicated value, U) lies either within the limits of variation of the indicated value permitted in the test (test passed, triangle in Figure A.1) or outside of these limits (test failed, circle in Figure A.1). If one of the permitted limits of variation, x_u or x_l, lies within the confidence interval (squares in Figure A.1), the number of measurements or the sample size can be increased up to a number of 25 to reduce the width $2 \cdot U$ of the confidence interval, in order to reach one of the two cases mentioned above, which are necessary for an unequivocal decision of passing the test or not.

In case the number of measurements or the sample size is already ~~25~~ 24, the test is passed if the mean $\overline{x}$ lies inside the permitted limits of variation (filled square) and the test is failed if the mean $\overline{x}$ lies outside the permitted limits of variation (open square).



Key

1 Confidence interval of the mean, width 2 U

2 Permitted upper limit of variation, x_u

3 Permitted lower limit of variation, x_l

Figure A.1 – Test for confidence interval

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

$$x_l < \overline{x} \pm U < x_u \quad \text{(A.1)}$$

If it turns out to be necessary to reduce the width $2 \cdot U$ of the confidence interval, the number of measurements should be increased.

A.2 Confidence interval for the mean, $\bar{x}$

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

$$(\bar{x} - U_{\mathrm{m}},\ \bar{x} + U_{\mathrm{m}}) \tag{A.2}$$

where U_{m} is the half-width of the confidence interval of $\bar{x}$ which is the expanded uncertainty of a mean value. When calculating $\bar{x}$ from n measurements, the half-width of the confidence interval at a confidence level of 95 % is given by (see ISO/IEC Guide 98-3:2008, C.3.2 and G.3, formula G.1d):

$$U_{\mathrm{m}} = \frac{t_{n-1}}{\sqrt{n}} \cdot s \tag{A.3}$$

where s is the standard deviation for the specific group of measurements, and t_{n-1} (coverage factor for the double sided confidence level of 95 %) is taken from Table A.1 for n measurements. For example, for n = 10, $U_{\mathrm{m}} = \frac{2{,}262}{\sqrt{10}} \cdot s = 0{,}72 \cdot s$.

Table A.1 – Student's *t*-value for a double sided 95 % confidence interval

n	t_{n-1}	$\frac{t_{n-1}}{\sqrt{n}}$
2	12,71	8,98
3	4,30	2,48
4	3,18	1,59
5	2,78	1,24
6	2,57	1,05
7	2,45	0,925
8	2,36	0,836
9	2,31	0,769
10	2,26	0,715
15	2,14	0,554
20	2,09	0,468
~~25~~ 24	2,06	~~0,413~~ 0,410
~~30~~ 25	~~2,05~~ 2,06	~~0,373~~ 0,413
~~40~~ 30	~~2,02~~ 2,05	~~0,320~~ 0,373
~~60~~ 40	~~2,00~~ 2,02	~~0,258~~ 0,320
~~120~~ 60	~~1,98~~ 2,00	~~0,181~~ 0,258
~~∞~~ 120	~~1,96~~ 1,98	0,181
∞	1,96	1,96 / $\sqrt{n}$

A.3 Confidence interval for a combined quantity

Suppose the mean values of w quantities $\bar{x}_i$ (i = 1..w) and the half-widths of the corresponding confidence intervals U_i (i = 1..w) to be given; the U_i are calculated according to formula (A.3). Let $\bar{x}$ be a combined quantity from these w mean values:

$$\bar{x} = f(\bar{x}_1, \bar{x}_2, .., \bar{x}_w) \tag{A.4}$$

Then the half-width of the confidence interval U_{com} for the combined quantity $\bar{x}$ represents the expanded uncertainty of $\bar{x}$ and is approximately given by:

$$U_{\mathrm{com}} \approx \sqrt{\sum_{i=1}^{w} \left(\frac{\partial \bar{x}}{\partial x_i} \cdot U_i \right)^2} \tag{A.5}$$

This is only valid, if the w quantities are normally distributed (see ISO/IEC Guide 98-3:2008, E.3.3) and not correlated. The correct way to determine the confidence interval for the combined quantity x is described in the ISO/IEC Guide 98-3:2008, G.4.1. Nevertheless, for the purpose of this document, formula (A.5) can be used as a good approximation. The following examples use formula (A.5).

EXAMPLE 1 $\bar{x} = \bar{x}_1 \pm \bar{x}_2$ hence $U_{\text{com}} \approx \sqrt{U_1^2 + U_2^2}$

in general $\bar{x} = \sum_{i=1}^{n} \bar{x}_i$ hence $U_{\text{com}} \approx \sqrt{\sum_{i=1}^{n} U_i^2}$

EXAMPLE 2 $\bar{x} = \dfrac{\overline{G}_1}{\overline{G}_{\text{r},0}}$ hence $U_{\text{com}} \approx \dfrac{\overline{G}_1}{\overline{G}_{\text{r},0}} \cdot \sqrt{\left(\dfrac{U_1}{\overline{G}_1}\right)^2 + \left(\dfrac{U_{\text{r},0}}{\overline{G}_{\text{r},0}}\right)^2}$

NOTE 1 U_1 and $U_{\text{r},0}$ are calculated according to formula (A.3).

Suppose group 1 of n = 10 dosemeters was irradiated to a conventional ~~true~~ quantity value of C_1 = 0,1 mSv. The reference group of n = 5 dosemeters was irradiated to $C_{\text{r},0}$ = 3 mSv.

The indicated values for the two groups are, for group 1:

0,094 mSv; 0,097 mSv; 0,086 mSv; 0,091 mSv; 0,092 mSv;
0,103 mSv; 0,093 mSv; 0,087 mSv; 0,087 mSv; 0,094 mSv.

and for the reference group:

2,82 mSv; 2,97 mSv; 3,04 mSv; 2,96 mSv; and 2,96 mSv.

From the above values, $\overline{G}_1 = 0{,}0924$, $\overline{G}_{\text{r},0} = 2{,}950$, s_1 = 0,00517 and $s_{\text{r},0}$ = 0,0800 are calculated. Using formula (A.3) leads to U_1 = 0,00370 and $U_{\text{r},0}$ = 0,0993. For the quotient $\dfrac{\overline{G}_1}{\overline{G}_{\text{r},0}} = 0{,}0313$, it results $U_{\text{com}} \approx 0{,}00164$. Thus, the term $\left(\dfrac{\overline{G}_1}{\overline{G}_{\text{r},0}} \pm U_{\text{com}}\right) \cdot \dfrac{C_{\text{r},0}}{C_1}$ results in 0,940 ± 0,049 representing the confidence interval of the relative response at a confidence level of 95 %: 0,89 to 0,99.

NOTE 2 The response values are R_1 = 0,924 and $R_{\text{r},0}$ = 0,983 leading to a relative response of r = 0,940.

Assume, that the relative response is allowed to be between 0,91 and 1,11. Assuming the expanded uncertainties of the conventional ~~true~~ quantity values C_1 and $C_{\text{r},0}$ to be $U_{C,\text{rel; r},0}$ = 2,5 % and $U_{C,\text{rel; }1}$ = 2,5 %, respectively, leads to $U_{C,\text{com}} = \sqrt{U_{C,\text{rel;r},0}^2 + U_{C,\text{rel;}1}^2} = 0{,}035$. This leads to the following allowed limits: 0,87 to 1,15.

In conclusion, the inequation $0{,}91 - U_{C,\text{com}} \le \left(\dfrac{\overline{G}_i}{\overline{G}_{\text{r},0}} \pm U_{\text{com}}\right) \cdot \dfrac{C_{\text{r},0}}{C_i} \le 1{,}11 + U_{C,\text{com}}$ becomes

0,87 ≤ 0,89.. 0,99 ≤ 1,15 and is fulfilled. This test is passed.

Annex B
(informative)

Causal connection between readout signals, indicated value and measured value

The causal connection between (readout) signal(s) (see 3.40), indicated value (see 3.14) and the measured value (see 3.22) is shown in the following Figure B.1.

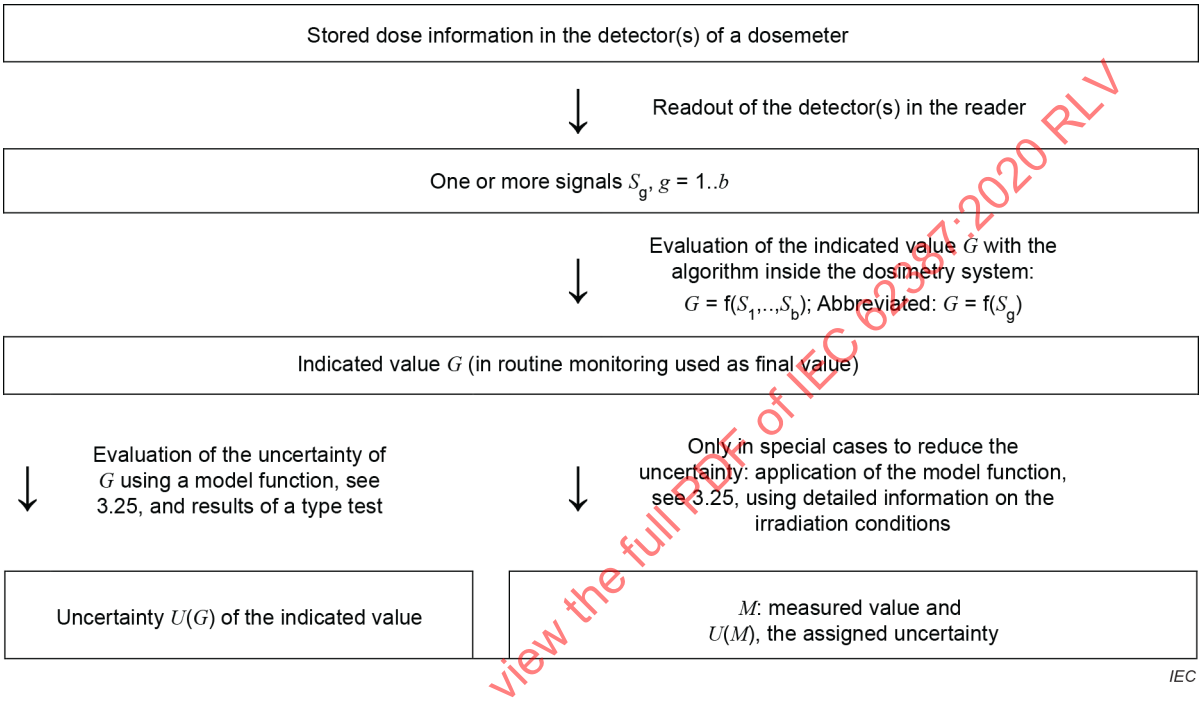


Figure B.1 – Data evaluation in dosimetry systems

The starting point of data evaluation is the stored dose information in the detector(s).

This information is read out and the reader generates one or more signals, for example the charge measured in a photomultiplier tube due to TL-light, called S_1: b = 1. In the case $b > 1$, this indicates that more than one signal can be present from one dosemeter.

Using this signal as a basis, the dosimetry system (computer or whatever) evaluates the value that will be indicated. To determine this indicated value G from the signal(s), a number of steps are automatically done inside the dosimetry system. Examples for these steps are the application of ~~a calibration factor, a~~ corrections for the detector sensitivity ~~factor~~ and reader calibration and the application of a computer algorithm for combining more than one signal. These steps are summarized in the function $f(S_g)$ (see 8.6). In routine monitoring, the indicated value G is used as the final result. In other words: the instrument constant, c_i, is unity, see 3.18. However, the uncertainty of G is not known up to this point.

The uncertainty $U(G)$ of the indicated value can be determined using a model function (see 3.25) and further information, for example results of a type test according to this document.

In case a very precise dose value shall be determined, for example in an accidental situation, detailed information on the irradiation conditions can be used to correct the indicated value. This can be done using a model function (see 3.25). The result is called measured value M because it is quite close to the traditionally called true dose value with a small uncertainty.

The two latter steps are explained in detail in IEC TR 62461.

Annex C
(informative)

Overview of the necessary actions that have to be performed for a type test according to this document

In Table C.1 a schedule for a type test for a dosemeter, that fulfils this document for the mandatory ranges, is given. Extending the rated ranges means that more irradiations have to be performed.

Table C.1 – Schedule for a type test of a dosemeter for $H_p(10)$ fulfilling the requirements within the mandatory ranges

Line	Characteristic under test	Action to be taken for the type test	Number of groups / dosemeters to be irradiated	Clause/ Sub-clause
1	Capability of the dosimetry system	Documentation of the manufacturer: check whether the mandatory ranges are covered	0 / 0	7
2	Requirements to the design of the dosimetry system	Documentation of the manufacturer: check whether the requirements are fulfilled and the evaluation algorithm is given	0 / 0	8
3	Effects of radiation not intended to be measured	Documentation of the manufacturer: check whether the response to neutron radiation is given	0 / 0	8.7
4	Instruction manual	Check the manual	0 / 0	9
5	Software, data and interfaces	Check the documentation of the manufacturer and perform simple tests	0 / 0	10
6	Relative response due to non-linearity	Perform irradiations	~~12 / 96~~ 9 / 72	11.3
7	Coefficient of variation, v			11.2
8	Overload, after-effects, and reusability	Perform irradiations	4 / 26	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	Check whether the construction of the dosemeter is symmetrical with respect to rotation, then perform irradiations	Sym. Constr.:24 / 96 Non-sym.: 48 / 192	11.5.1
10	Relative response due to mean beta radiation energy	Perform irradiations	1 / 5	11.5.2
11	As in line 9 and 10 but new reference direction opposite to that one used	Check whether the information is given on the dosemeter or whether the dosemeter is symmetrical with respect to detector plane; if both is not the case, perform irradiations	Mostly 0 / 0 Maybe as line 9	8.4 f)
12	Radiation incidence from the side of the dosemeter	Check by looking at the construction of the dosemeter: side walls thicker than front? If not, perform irradiations	Mostly 0 / 0 Maybe 6 / 24	11.8
13	Response to mixed irradiations	Check by understanding the evaluation algorithm; if it is not additive, use irradiations from Clause 11 and perform calculations according to Clause 12 and Annex F	Mostly 0 / 0 Maybe 3 / 12	12
14	Relative response due to environmental performance requirements	Perform irradiations and additional influences, for example storing of three groups for a time of t_{max}	~~23/176~~ 21/126	13
15	Deviation due to electromagnetic performance requirements	Perform irradiations and additional influences	~~8 / 107~~ 8 / 130	14
16	Deviation due to mechanical performance requirements	Perform irradiations and additional influences	4 / 24	15

Annex D
(informative)

Usage categories of passive dosemeters

The usage categories, given in Table D.1 can be used to categorize passive dosemeters for approval purposes.

Table D.1 – Usage categories of passive dosemeters

Main Category	Symbol	Mandatory range of use	Optional extensions		
			for energy range	for lower limit of dose range	for upper limit of dose range
$H_p(10)$ photon radiation	**G** (gamma)	80 keV to 1,25 MeV [a] 0,1 mSv to 1 Sv [b]	**m** (mid): lower limit 60 keV **l** (low): lower limit 20 keV **h** (high): includes 7 MeV	**f**: lower limit 0,01 mSv	**a** (accident): upper limit 10 Sv
$H^*(10)$ photon radiation	**E** (environment)	80 keV to 1,25 MeV [a] 0,1 mSv to 1 Sv [b]	**m** (mid): lower limit 60 keV **l** (low): lower limit 20 keV **h** (high): includes 7 MeV	**f**: lower limit 0,01 mSv	**a** (accident): upper limit 10 Sv
$H_p(0,07)$ photon radiation	**S** (skin)	30 keV to 250 keV 1 mSv to 10 Sv [b]	**l**: lower limit 20 keV **n**: lower limit 15 keV	**g**: lower limit 0,1 mSv	
$H_p(0,07)$ beta radiation	**B** (beta)	0,8 MeV (E_{mean}) [a] 1 mSv to 10 Sv [b]	**l**: lower limit 60 keV (E_{mean}) [a]	**g**: lower limit 0,1 mSv	

[a] Mandatory energy range

[b] Mandatory measuring range

Example 1: A personal photon dosemeter for a nuclear plant may be classified as **Gmh**.

Example 2: An environmental photon dosemeter for a location near a nuclear plant may be classified as **Emhf**.

Example 3: A personal photon-beta dosemeter for medical use may be classified as **Sng-Blg**.

Annex ~~E~~ D
(informative)

Uncertainty of dosimetry systems

~~If a dosimetry systems fulfils all requirements of this International standard and if, in addition, the two conditions a) and b) given below are fulfilled, then the dosimetry system is in line with the recommendations on accuracy stated in paragraph 251 of ICRP 75:1997. That means, the response of the dosimetry systems lies within a factor of 1,5 in either direction for photon radiation at a 95 % confidence level. This is valid if the dosemeter is worn correctly at the representative part of the body and if all influence quantities are within their rated ranges.~~

~~a) For all relative responses r_q determined according to 13.2 to 13.9, the inequality~~

$$\sqrt{\sum_{13.2\ \text{to}\ 13.9} \left(\frac{1}{r_q} - 1\right)^2} \leq 20\ \%$$ ~~is valid~~

~~b) For all indicated values $\overline{G}_i$ determined according to 14.3, the inequality~~

$$\sqrt{\sum_{i=2}^{8} \left\{ \left(\max \left| \overline{G}_i - \overline{G}_1 \pm U_\text{m} \right| \right)^2 \right\}} \leq 1{,}1 \cdot H_\text{low}$$ ~~is valid.~~

~~NOTE 1 The maximum is built over the two possibilities $\left|\overline{G}_i - \overline{G}_1 + U_\text{m}\right|$ and $\left|\overline{G}_i - \overline{G}_1 - U_\text{m}\right|$.~~

~~NOTE 2 The expression $\sqrt{..}$ represents the quadratic square sum of the deviations.~~

It is advisable that the dosimetry system is in line with the recommendations on accuracy stated in paragraph 251 of ICRP 75:1997. That means, the response of the dosimetry systems in routine use shall lie within a factor of 1,5 in either direction for photon radiation at a 95 % (k = 2) confidence level. This is the case if the dosemeter is worn correctly at the representative part of the body, if all influence quantities are within their rated ranges, and if the standard uncertainty determined according to IEC TR 62461 is less than or equal to 17 % (k = 1).

Annex F
(informative)

Conversion coefficients $h_{pK}(3;\alpha)$, $h_{pK}(0,07;\alpha)$, and $h'_K(0,07;\alpha)$ from air kerma, K_a, to the dose equivalent $H_p(3)$, $H_p(0,07)$, and $H'(0,07)$, respectively, for radiation qualities defined in ISO 4037-1

In Tables F.1 and F.2 conversion coefficients from air kerma to the dose equivalent $H_p(3)$ are given for the narrow spectrum series and for gamma radiation qualities, respectively. In Table F.3 conversion coefficients from air kerma to the dose equivalents $H_p(0,07)$ are given for gamma radiation qualities. In Table F.4 conversion coefficients from air kerma to the dose equivalents $H'(0,07)$ are given for high energy x ray and gamma radiation qualities. The values were obtained by folding fluence spectra with the corresponding conversion coefficients for mono-energetic photons, see Behrens (2011).

The values given in Tables F.1, F.2, F.3 and F.4 shall only be used as long as such values are not included in ISO 4037-3 or in any other documents or scientific publications.

Table F.1 – Conversion coefficients $h_{pK}(3;N,\alpha)$ from air kerma, K_a, to the dose equivalent $H_p(3)$ for radiation qualities defined in ISO 4037-1 and for the slab phantom, reference distance 2 m

Radiation quality	Irradiation distance m	Beam diameter [a] cm	$h_{pK}(3;N,\alpha)$ in Sv/Gy for angle of incidence α of					
			0°	15°	30°	45°	60°	75°
N-10	1,0 – 2,0	25	0,131	0,122	0,098	0,061	0,0213	0,00099
N-15	1,0 – 2,0	25	0,42	0,41	0,38	0,32	0,238	0,129
N-20	1,0 – 2,0	25	0,66	0,66	0,63	0,58	0,49	0,31
N-25	1,0 – 3,0	23	0,88	0,88	0,86	0,80	0,71	0,49
N-30	1,0 – 3,0	20	1,04	1,04	1,03	0,97	0,89	0,65
N-40	1,0 – 3,0	16	1,29	1,29	1,28	1,22	1,13	0,91
N-60	1,0 – 3,0	11	1,63	1,63	1,60	1,54	1,43	1,17
N-80	1,0 – 3,0	11	1,80	1,79	1,77	1,71	1,59	1,33
N-100	1,0 – 3,0	11	1,81	1,80	1,78	1,73	1,62	1,39
N-120	1,0 – 3,0	11	1,74	1,73	1,72	1,68	1,59	1,38
N-150	1,0 – 3,0	11	1,66	1,65	1,65	1,62	1,55	1,35
N-200	1,0 – 3,0	11	1,53	1,53	1,53	1,51	1,47	1,32
N-250	1,0 – 3,0	11	1,46	1,46	1,45	1,45	1,41	1,30
N-300	1,0 – 3,0	11	1,41	1,41	1,40	1,40	1,37	1,28
N-350	1,0 – 3,0	11	1,37	1,37	1,37	1,37	1,35	1,27
N-400	1,0 – 3,0	11	1,33	1,34	1,34	1,35	1,33	1,27

[a] Approximate locus of the 98 % isodose contour with respect to the dose in the centre of the phantom.

Table F.2 – Conversion coefficients $h_{pK}(3;S,\alpha)$ and $h_{pK}(3;R,\alpha)$ from air kerma, K_a, to the dose equivalent $H_p(3)$ for radiation qualities defined in ISO 4037-1 and for the slab phantom

Radiation quality	Irradiation distance m	Beam diameter [a] cm	Build-up layer [b] mm	k_{PMMA} [c]	$h_{pK}(3;S,\alpha)$ and $h_{pK}(3;R,\alpha)$ in Sv/Gy for angle of incidence α of					
					0°	15°	30°	45°	60°	75°
S-Cs	1,5 – 4,0	15	2	1,00	1,22	1,22	1,22	1,25	1,25	1,22
S-Co	1,5 – 4,0	15	4	1,00	1,16	1,17	1,17	1,18	1,19	1,19
R-C	1,0 – 5,0	15	25	0,94	1,12	1,12	1,12	1,12	1,13	1,15
R-F	1,0 – 5,0	15	25	0,94	1,12	1,12	1,12	1,12	1,13	1,14

[a] Approximate locus of the 98 % isodose contour with respect to the dose in the centre of the phantom.

[b] A plate of polymethyl-methacrylate (PMMA) with a cross-sectional area of 30 cm × 30 cm and a thickness sufficient to secure completed build-up should be positioned in front of the dosemeter.

[c] The modification of the radiation field by introducing the PMMA plate should be taken into account by multiplying the conversion coefficient with the correction factor k_{PMMA}.

Table F.3 – Conversion coefficients $h_{pK}(0,07;S,\alpha)$ and $h_{pK}(0,07;R,\alpha)$ from air kerma, K_a, to the dose equivalent $H_p(0,07)$ for radiation qualities defined in ISO 4037-1 and for the rod, pillar, and slab phantom

Radiation quality	Irradiation distance m	Beam diameter [a] cm	Build-up layer [b] mm	k_{PMMA} [c]	$h_{pK}(0,07)_{Rod}$ Sv/Gy for α	$h_{pK}(0,07)_{Pillar}$ Sv/Gy for α	$h_{pK}(0,07;S,\alpha)_{Slab}$ and $h_{pK}(0,07;R,\alpha)_{Slab}$ in Sv/Gy for α					
					0° .. ± 60°	0° .. ± 60°	0°	15°	30°	45°	60°	75°
S-Cs	1,5 – 4,0	15	2	1,00	1,13	1,14	1,21	1,22	1,22	1,23	1,26	1,28
S-Co	1,5 – 4,0	15	4	1,00	1,12	1,13	1,17	1,17	1,17	1,18	1,21	1,23
R-C	1,0 – 5,0	15	25	0,94	1,11	1,12	1,12	1,12	1,12	1,13	1,14	1,17
R-F	1,0 – 5,0	15	25	0,94	1,11	1,12	1,13	1,12	1,12	1,12	1,13	1,15

[a] Approximate locus of the 98 % isodose contour with respect to the dose in the centre of the phantom.

[b] A plate of polymethyl-methacrylate (PMMA) with a cross-sectional area of 30 cm × 30 cm and a thickness sufficient to secure completed build-up should be positioned in front of the dosemeter.

[c] The modification of the radiation field by introducing the PMMA plate should be taken into account by multiplying the conversion coefficient with the correction factor k_{PMMA}.

Table F.4 – Conversion coefficients $h'_K(0,07;N,\alpha)$, $h'_K(0,07;S,\alpha)$, and $h'_K(0,07;R,\alpha)$ from air kerma, K_a, to $H'(0,07)$ for radiation qualities defined in ISO 4037-1

Radiation quality	Irradiation distance m	Beam diameter [a] cm	Build-up layer [b] mm	k_{PMMA} [c]	$h'_K(0,07;N,\alpha)$, $h'_K(0,07;S,\alpha)$, and $h'_K(0,07;R,\alpha)$ in Sv/Gy for α							
					0°	15°	30°	45°	60°	75°	90°	180°
N-350	1,0 – 3,0	11	-	-	1,32	1,32	1,32	1,32	1,31	1,31	1,17	0,130
N-400	1,0 – 3,0	11	-	-	1,30	1,30	1,30	1,30	1,30	1,30	1,16	0,139
S-Cs	1,5 – 4,0	15	2	1,00	1,20	1,20	1,20	1,20	1,20	1,18	1,07	0,22
S-Co	1,5 – 4,0	15	4	1,00	1,16	1,16	1,16	1,16	1,16	1,14	1,04	0,35
R-C	1,0 – 5,0	15	25	0,94	1,12	1,12	1,12	1,12	1,12	1,09	1,01	0,57
R-F	1,0 – 5,0	15	25	0,94	1,11	1,11	1,11	1,11	1,11	1,09	1,02	0,62

[a] Approximate locus of the 98 % isodose contour with respect to the dose in the centre of the phantom.

[b] A plate of polymethyl-methacrylate (PMMA) with a cross-sectional area of 30 cm × 30 cm and a thickness sufficient to secure completed build-up should be positioned in front of the dosemeter.

[c] The modification of the radiation field by introducing the PMMA plate should be taken into account by multiplying the conversion coefficient with the correction factor k_{PMMA}.

Annex G
(informative)

Conversion coefficients $h_{pD}(0,07;source;\alpha)$ and $h_{pD}(3;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(0,07)$ and $H_p(3)$, respectively, for radiation qualities defined in ISO 6980-1

In Table G.1 conversion coefficients from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(3)$ are given for $^{90}Sr/^{90}Y$ and ^{106}Ru series 1 radiation fields. Table G.2 conversion coefficients from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(0,07)$ are given for ^{106}Ru series 1 radiation fields. The values were obtained by measurements with a beta primary standard for absorbed dose to tissue, see Behrens and Buchholz (2011).

The values given in the following tables shall only be used as long as such values are not included in ISO 6980-3 or in any other documents or scientific publications.

Table G.1 – Measured conversion coefficients $h_{pD}(3;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(3)$ for the slab phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(3;source;\alpha)$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
$^{90}Sr/^{90}Y$	yes	30	0,43	0,40	0,32	0,20	0,098	0,032
$^{106}Ru/^{106}Rh$	yes	30	0,76	0,72	0,63	0,47	0,26	0,095

Table G.2 – Measured conversion coefficients $h_{pD}(0,07;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(0,07)$ for the slab phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(0,07;source;\alpha)$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
$^{106}Ru/^{106}Rh$	yes	30	1,00	1,00	1,04	1,13	1,19	1,00

Annex E
(informative)

Conversion coefficients $h_{pD}(0,07;source;\alpha)$, $h'_{D}(0,07;source;\alpha)$, $h_{pD}(3;source;\alpha)$, and $h'_{D}(3;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the corresponding dose equivalent quantities for radiation qualities defined in ISO 6980-1

In Tables E.1 to E.5 conversion coefficients from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the different dose equivalent quantites are given for radiation qualities defined in ISO 6980-1. The values were obtained by measurements with a beta primary standard for absorbed dose to tissue (embedded in a slab phantom), see Behrens and Buchholz (2011). Corrections to account for the difference from the slab (used to determine $D_p(0,07)$) to other phantoms (to be used during calibration and irradiation of dosemeters) and to the ICRU sphere were taken into account, see Behrens (2015). The standard uncertainties (k = 1) are stated in the tables.

The values given in the following tables shall only be used as long as such values are not included in ISO 6980-3 or in any other documents or scientific publications.

Table E.1 – Conversion coefficients $h_{pD}(0,07;source;\alpha)_{slab}$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(0,07)$ for the slab phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(0,07;source;\alpha)_{slab}$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
^{147}Pm	no	11	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{147}Pm	yes	20	1,000 ± 0,000	0,960 ± 0,002	0,870 ± 0,007	0,720 ± 0,013	0,530 ± 0,016	n.a.
^{85}Kr	yes	30	1,000 ± 0,000	0,990 ± 0,001	0,960 ± 0,005	0,880 ± 0,010	0,720 ± 0,014	0,490 ± 0,015
^{85}Kr	yes	50	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	11	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	20	1,000 ± 0,000	1,020 ± 0,001	1,060 ± 0,006	1,140 ± 0,013	1,210 ± 0,024	n.a.
^{90}Sr/^{90}Y	no	30	1,000 ± 0,000	1,010 ± 0,001	1,060 ± 0,006	1,130 ± 0,013	1,160 ± 0,023	0,910 ± 0,027
^{90}Sr/^{90}Y	no	50	1,000 ± 0,000	1,010 ± 0,001	1,050 ± 0,006	1,100 ± 0,013	1,100 ± 0,022	0,840 ± 0,025
^{90}Sr/^{90}Y	yes	30	1,000 ± 0,000	1,010 ± 0,001	1,060 ± 0,006	1,120 ± 0,013	1,140 ± 0,023	0,860 ± 0,025
^{90}Sr/^{90}Y	yes	50	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	11	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	20	1,000 ± 0,000	1,011 ± 0,001	1,06 ± 0,006	1,151 ± 0,013	1,256 ± 0,025	n.a.
^{106}Ru/^{106}Rh	yes	30	1,000 ± 0,000	0,998 ± 0,001	1,039 ± 0,006	1,127 ± 0,013	1,195 ± 0,024	1,003 ± 0,030
^{106}Ru/^{106}Rh	yes	50	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.2 – Conversion coefficients $h_{pD}(0,07;source;\alpha)_{rod}$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(0,07)$ for the rod phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(0,07;source;\alpha)_{rod}$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
^{147}Pm	no	11	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{147}Pm	yes	20	1,000 ± 0,005	0,960 ± 0,005	0,870 ± 0,008	0,720 ± 0,013	0,534 ± 0,016	n.a.
^{85}Kr	yes	30	1,000 ± 0,005	0,990 ± 0,005	0,960 ± 0,007	0,880 ± 0,013	0,728 ± 0,016	0,506 ± 0,015
^{85}Kr	yes	50	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	11	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	20	0,987 ± 0,005	1,006 ± 0,005	1,042 ± 0,008	1,122 ± 0,014	1,227 ± 0,025	n.a.
$^{90}Sr/^{90}Y$	no	30	0,987 ± 0,005	0,996 ± 0,005	1,042 ± 0,008	1,112 ± 0,014	1,176 ± 0,024	1,052 ± 0,032
$^{90}Sr/^{90}Y$	no	50	0,987 ± 0,005	0,996 ± 0,005	1,032 ± 0,008	1,082 ± 0,014	1,115 ± 0,023	0,971 ± 0,029
$^{90}Sr/^{90}Y$	yes	30	0,987 ± 0,005	0,996 ± 0,005	1,042 ± 0,008	1,102 ± 0,014	1,156 ± 0,024	0,994 ± 0,030
$^{90}Sr/^{90}Y$	yes	50	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	11	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	20	0,987 ± 0,005	0,993 ± 0,006	1,037 ± 0,008	1,120 ± 0,014	1,251 ± 0,026	n.a.
$^{106}Ru/^{106}Rh$	yes	30	0,987 ± 0,005	0,980 ± 0,006	1,016 ± 0,008	1,097 ± 0,014	1,190 ± 0,025	1,156 ± 0,035
$^{106}Ru/^{106}Rh$	yes	50	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.3 – Conversion coefficients $h'_D(0,07;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H'(0,07)$ for the ICRU sphere for radiation qualities defined in ISO 6980-1

Source			$H'_D(0,07;source;\alpha)$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
^{147}Pm	no	11	1,000 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.
^{147}Pm	yes	20	1,000 ± 0,006	0,960 ± 0,007	0,870 ± 0,012	0,720 ± 0,014	0,530 ± 0,016	n.a.
^{85}Kr	yes	30	1,000 ± 0,006	0,990 ± 0,007	0,96 ± 0,009	0,88 ± 0,013	0,720 ± 0,019	0,490 ± 0,016
^{85}Kr	yes	50	1,000 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	11	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	20	1,000 ± 0,005	1,020 ± 0,005	1,060 ± 0,008	1,140 ± 0,016	1,210 ± 0,025	n.a.
^{90}Sr/^{90}Y	no	30	1,000 ± 0,005	1,010 ± 0,005	1,060 ± 0,008	1,130 ± 0,015	1,160 ± 0,024	0,910 ± 0,028
^{90}Sr/^{90}Y	no	50	1,000 ± 0,005	1,010 ± 0,005	1,050 ± 0,008	1,100 ± 0,015	1,100 ± 0,023	0,840 ± 0,026
^{90}Sr/^{90}Y	yes	30	1,000 ± 0,005	1,010 ± 0,005	1,060 ± 0,008	1,120 ± 0,015	1,140 ± 0,024	0,860 ± 0,027
^{90}Sr/^{90}Y	yes	50	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	11	1,000 ± 0,007	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	20	1,000 ± 0,007	1,011 ± 0,008	1,060 ± 0,010	1,151 ± 0,016	1,256 ± 0,026	n.a.
^{106}Ru/^{106}Rh	yes	30	1,000 ± 0,007	0,998 ± 0,008	1,039 ± 0,010	1,127 ± 0,016	1,195 ± 0,025	1,003 ± 0,031
^{106}Ru/^{106}Rh	yes	50	1,000 ± 0,007	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.4 – Conversion coefficients $h_{pD}(3;source;\alpha)_{cylinder}$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(3)$ for the cylinder phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(3;source;\alpha)_{cylinder}$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
$^{90}Sr/^{90}Y$	no	11	0,501 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	20	0,495 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	30	0,476 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	50	0,440 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	yes	30	0,431 ± 0,004	0,407 ± 0,004	0,321 ± 0,004	0,210 ± 0,004	0,105 ± 0,004	0,037 ± 0,002
$^{90}Sr/^{90}Y$	yes	50	0,384 ± 0,003	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	11	0,760 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	20	0,771 ± 0,006	0,743 ± 0,006	0,659 ± 0,008	0,500 ± 0,010	0,291 ± 0,009	n.a.
$^{106}Ru/^{106}Rh$	yes	30	0,757 ± 0,006	0,716 ± 0,006	0,641 ± 0,007	0,486 ± 0,010	0,284 ± 0,009	0,114 ± 0,005
$^{106}Ru/^{106}Rh$	yes	50	0,715 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.5 – Conversion coefficients $h'_D(3;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H'(3)$ for the ICRU sphere for radiation qualities defined in ISO 6980-1

Source			$H'_D(3;source;\alpha)$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
$^{90}Sr/^{90}Y$	no	11	0,501 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	20	0,495 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	30	0,476 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	50	0,44 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	yes	30	0,431 ± 0,004	0,402 ± 0,004	0,320 ± 0,004	0,208 ± 0,004	0,104 ± 0,004	0,035 ± 0,002
$^{90}Sr/^{90}Y$	yes	50	0,384 ± 0,003	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	11	0,760 ± 0,007	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	20	0,771 ± 0,007	0,743 ± 0,006	0,657 ± 0,008	0,496 ± 0,010	0,284 ± 0,009	n.a.
$^{106}Ru/^{106}Rh$	yes	30	0,757 ± 0,007	0,716 ± 0,006	0,639 ± 0,008	0,483 ± 0,010	0,277 ± 0,009	0,107 ± 0,005
$^{106}Ru/^{106}Rh$	yes	50	0,715 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.

Annex ~~H~~ F
(informative)

Computational method of test for mixed irradiations

In Figure F.1 a flow chart of a program performing the method of test according to 12.2 is shown. The following notations are valid:

N = 1, 2, …, N_{max} is the pointer to the table entry containing the signals (element responses) S_g(K) for the radiation quality K (g = 1,.b). For example, N = 2 corresponds to "N-20; 15° up".

j = 1, 2, …, (N_{max} – N) is the offset from N to point to the table entry containing the signals (element responses) S_g(L) for the radiation quality L (g = 1,.b). For example, for N = 2 and j = 3 corresponds to row 2+3 = 5: "N-20; 15° right".

i is the weight index from 1 to 9, equivalent to 10 % to 90 % for the dose values C_K and 90 % to 10 % for C_L, respectively. For the above given example, i = 2 corresponds to 20 % dose of "N-20; 15° up" and 80 % dose of "N-20; 15° right".

An example of a dosemeter signal table is given ~~below~~ in Table F.1.

Table F.1 – Example of dosemeter response table and range limits

N	Radiation Quality	r_{min}	r_{max}	S_1	S_2	…	S_b
1	N-20; 0°	0,67	2,00	0,80	1,20	…	3,50
2	N-20; 15° up	0,67	2,00	0,72	1,08	…	3,15
3	N-20; 15° down	0,67	2,00	0,70	1,05	…	3,10
4	N-20; 15° left	0,67	2,00	0,63	0,95	…	2,79
5	N-20; 15° right	0,67	2,00	0,65	0,99	…	2,85
6	N-20; 30° up	0,67	2,00	0,70	1,03	…	3,10
…	…	0,67	2,00	…	…	…	…
	N-30; 0°	0,69	1,82	…	…	…	…
	N-30; 15° up	0,69	1,82	…	…	…	…
	…	0,69	1,82	…	…	…	…
	N-80; 0°	0,71	1,67	…	…	…	…
	N-80; 15° up	0,71	1,67	…	…	…	…
	…	0,71	1,67	…	…	…	…
	S-Co; 0°	0,71	1,67	…	…	…	…
	S-Co; 15° up	0,71	1,67	…	…	…	…
	…	0,71	1,67	…	…	…	…
	^{90}Sr/^{90}Y; 0°	0,67	2,00	…	…	…	…
	^{90}Sr/^{90}Y; 15° up	0,67	2,00	…	…	…	…
N_{max}	…	0,67	2,00	…	…	…	…

The required range of response weighted with i and (10 – i) is calculated from the ranges of response for the radiation qualities K and L, $r_{min,K}$ .. $r_{max,K}$ and $r_{min,L}$ .. $r_{max,L}$, by $r_{min,w} = \frac{r_{min,K} \cdot i + r_{min,L} \cdot (10 - i)}{10}$ and $r_{max,w} = \frac{r_{max,K} \cdot i + r_{max,L} \cdot (10 - i)}{10}$.

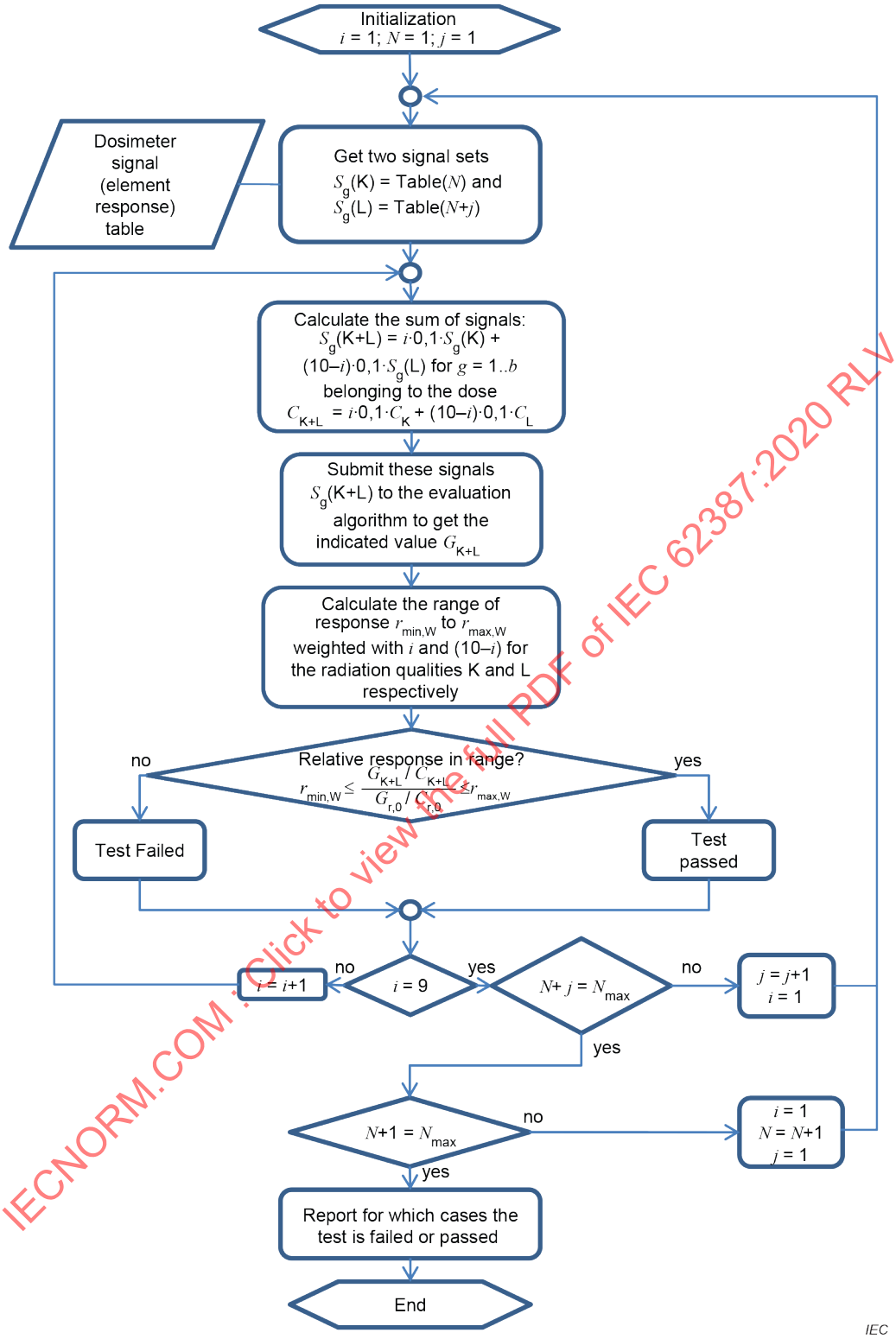


Figure F.1 – Flow chart of a computer program to perform tests according to 12.2

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IEC 62387

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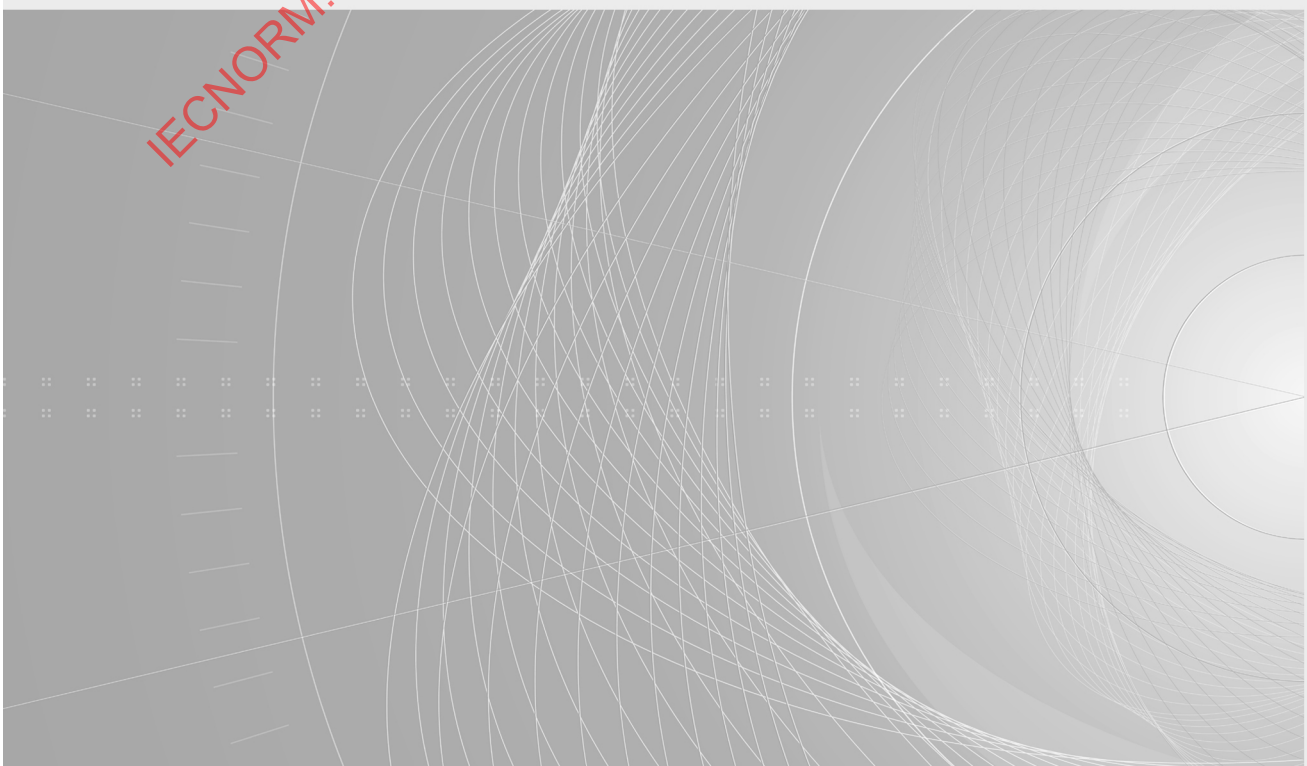
INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Radiation protection instrumentation – Dosimetry systems with integrating passive detectors for individual, workplace and environmental monitoring of photon and beta radiation

Instrumentation pour la radioprotection – Systèmes dosimétriques avec détecteurs intégrés passifs pour le contrôle radiologique individuel, du lieu de travail et de l'environnement des rayonnements photoniques et bêta



IEC 62387:2020-01(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RADIATION PROTECTION INSTRUMENTATION – DOSIMETRY SYSTEMS WITH INTEGRATING PASSIVE DETECTORS FOR INDIVIDUAL, WORKPLACE AND ENVIRONMENTAL MONITORING OF PHOTON AND BETA RADIATION

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62387 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition of IEC 62387 published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- Modification of title.
- Addition of performance requirements for dosemeters to measure $H'(3)$ for both photon and beta radiation.
- Adoption of the cylinder instead of the slab phantom for the quantity $H_p(3)$.
- Correction and clarification of several subclauses to obtain a better applicability.

The text of this standard is based on the following documents:

FDIS	Report on voting
45B/945/FDIS	45B/954/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

A dosimetry system may consist of the following elements:

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

b) a “dosemeter”, that incorporates some means of identification and contains one or more detectors and may contain electronic components, e.g. for the readout (e.g., in a direct ion storage (DIS) dosemeter);

c) a “reader” which is used to readout the stored information (signal) from the detector, in order to determine the radiation dose;

d) a “computer” with appropriate “software” to control the reader, store the signals transmitted from the reader, calculate, display and store the evaluated dose in the form of an electronic file or paper copy;

e) “additional equipment” and documented procedures (instruction manual) for performing associated processes such as deleting stored dose information, cleaning dosemeters, or those needed to ensure the effectiveness of the whole system.

RADIATION PROTECTION INSTRUMENTATION – DOSIMETRY SYSTEMS WITH INTEGRATING PASSIVE DETECTORS FOR INDIVIDUAL, WORKPLACE AND ENVIRONMENTAL MONITORING OF PHOTON AND BETA RADIATION

1 Scope

This document applies to all kinds of passive dosimetry systems that are used for measuring:

– the personal dose equivalent $H_p(10)$ (for individual whole body monitoring),

– the personal dose equivalent $H_p(3)$ (for individual eye lens monitoring),

– the personal dose equivalent $H_p(0{,}07)$ (for both individual whole body skin and local skin for extremity monitoring),

– the ambient dose equivalent $H^*(10)$ (for workplace and environmental monitoring),

– the directional dose equivalent $H'(3)$ (for workplace and environmental monitoring), or

– the directional dose equivalent $H'(0{,}07)$ (for workplace and environmental monitoring).

This document applies to dosimetry systems that measure external photon and/or beta radiation in the dose range between 0,01 mSv and 10 Sv and in the energy ranges given in Table 1. All the energy values are mean energies with respect to the fluence. The dosimetry systems usually use electronic devices for the data evaluation and thus are often computer controlled.

Table 1 – Mandatory and maximum energy ranges covered by this document

Measuring quantity	Mandatory mean energy range for photon radiation	Maximum mean energy range for testing photon radiation	Mandatory mean energy range for beta-particle radiation[a]	Maximum mean energy range for testing beta-particle radiation[a]
$H_p(10)$, $H^*(10)$	80 keV to 1,25 MeV[b]	12 keV to 7 MeV	–	–
$H_p(3)$, $H'(3)$	30 keV to 250 keV	8 keV to 7 MeV	0,8 MeV[c]	0,7 MeV[c] to 1,2 MeV
$H_p(0{,}07)$, $H'(0{,}07)$	30 keV to 250 keV	8 keV to 1,25 MeV[b]	0,24 MeV to 0,8 MeV	0,07 MeV[d] to 1,2 MeV[e]

[a] The following beta radiation sources are suggested for the different mean energies: For 0,06 MeV: ^{147}Pm; for 0,8 MeV: ^{90}Sr/^{90}Y; for 1,2 MeV: ^{106}Ru/^{106}Rh.

[b] 1,25 MeV is the mean energy of photon radiation from ^{60}Co.

[c] For beta-particle radiation, an energy of 0,7 MeV is required to reach the radiation sensitive layers of the eye lens in a depth of about 3 mm (approximately 3 mm of ICRU tissue).

[d] For beta-particle radiation, an energy of 0,07 MeV is required to penetrate the dead layer of skin of 0,07 mm (approximately 0,07 mm of ICRU tissue).

[e] 0,07 MeV, 0,8 MeV and 1,2 MeV beta mean energy are almost equivalent to an E_{max} of 0,225 MeV, 2,27 MeV and 3,54 MeV, respectively.

NOTE 1 In this document, “dose” means dose equivalent, unless otherwise stated.

NOTE 2 For $H_p(10)$ and $H^*(10)$ no beta radiation is considered. Reasons:

a) $H_p(10)$ and $H^*(10)$ are a conservative estimate for the effective dose which is not a suitable quantity for beta radiation.

b) No conversion coefficients are available in ICRU 56, ICRU 57 or ISO 6980-3.

NOTE 3 The maximum energy ranges are the energy limits within which type tests according to this document are possible.

NOTE 4 Direct ion storage (DIS) dosemeters are covered in this document as they are often operated without an online display but a separate reader.

The test methods concerning the design (Clause 8), the instruction manual (Clause 9), the software (Clause 10), environmental influences (Clause 13), electromagnetic influences (Clause 14), mechanical influences (Clause 15), and the documentation (Clause 16) are independent of the type of radiation. Therefore, they can also be applied to other dosimetry systems, e.g. for neutrons, utilizing the corresponding type of radiation for testing.

This document is intended to be applied to dosimetry systems that are capable of evaluating doses in the required quantity and unit (Sv) from readout signals in any quantity and unit. The only correction that may be applied to the evaluated dose (indicated value) is the one resulting from natural background radiation using extra dosemeters.

NOTE 5 The correction due to natural background can be made before or after the dose calculation.

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.

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

ISO 4037 (all parts), *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy*

ISO 4037-3:2019, *Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*

ISO 6980 (all parts), *Nuclear energy – Reference beta-particle radiation*

ISO 6980-3, *Nuclear energy – Reference beta-particle radiation – Part 3: Calibration of area and personal dosemeters and the determination of their response as a function of beta radiation energy and angle of incidence*

ISO 8529 (all parts), *Reference neutron radiations*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

Several quantities with specific subscripts are explained in Table 6.

3.1
ambient dose equivalent
$H^*(d)$
dose equivalent at a point in a radiation field, 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 to entry: The recommended depth, d, for environmental monitoring in terms of $H^*(d)$ is 10 mm, and $H^*(d)$ may be written as $H^*(10)$.

[SOURCE: IEC 60050-395:2014, 395-05-43 – Note 1 to entry is note 3 in the source]

3.2
calibration coefficient
N_0
quotient of the conventional quantity value to be measured and the corrected indication of the dosemeter, $G_{r,0}$, normalized to reference conditions

Note 1 to entry: The calibration coefficient for the reference radiation quality U and the angle of incidence α is equivalent to the calibration factor multiplied by the instrument coefficient. It is given by

$$N_0 = \frac{C_{r,0}}{G_{r,0}} = C_f(U,\alpha)\cdot c_i$$

where

$C_{r,0}$ is the conventional quantity value, see 3.5

$G_{r,0}$ is the corrected indication, see 3.14

$C_f(U,\alpha)$ is the calibration factor for the radiation quality U and the angle of incidence α, see 3.3, and

c_i is the instrument constant, see 3.18.

Concerning the dimension of the calibration factor and the calibration coefficient, see notes to 3.3 and 3.18.

Note 2 to entry: The reciprocal of the calibration coefficient is the response under reference conditions. The value of the calibration factor may vary with the magnitude of the quantity to be measured. In such cases a dosemeter is said to have a non-constant response (or a non-linear indication).

[SOURCE: ISO 29661:2012, 3.1.5, modified – Note 3 to entry has been deleted]

3.3
calibration factor
$C_f(U,\alpha)$
factor by which the product of the corrected indication, $G_{r,0}$, and the associated instrument constant, c_i, of the dosemeter is multiplied to obtain the conventional quantity value to be measured under reference conditions

Note 1 to entry: The calibration factor is dimensionless.

[SOURCE:ISO 29661:2012, 3.1.7]

3.4
coefficient of variation
v
ratio of the standard deviation s to the arithmetic mean $\overline{G}$ of a set of n indicated values G_j (indicated value)

$$v = \frac{s}{\overline{G}} = \frac{1}{\overline{G}}\sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(G_j - \overline{G}\right)^2}$$

3.5
conventional quantity value
C
quantity value attributed by agreement to a quantity for a given purpose

Note 1 to entry: The conventional quantity value C 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]

3.6
correction for non-linearity
r_n
quotient of the response R_n under conditions where only the value of the dose equivalent is varied, and the reference response R_0

$$r_n = \frac{R_n}{R_0}$$

Note 1 to entry: For a linear dosimetry system, r_n is equal to unity.

3.7
coverage factor
k
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

Note 1 to entry: A coverage factor k is typically in the range 2 to 3.

Note 2 to entry: In case of a normal distribution, using a coverage factor of 2 results in an expanded uncertainty that defines an interval around the result of a measurement that contains approximately 95 % of the distribution of values that could reasonably be attributed to the measurand. For other distributions, the coverage factor may be larger.

[SOURCE: GUM 2.3.6:1995, modified – The symbol k has been added]

3.8
detector
radiation detector
apparatus or substance used to convert incident ionizing radiation energy into a signal suitable for indication and/or measurement an apparatus or substance which, in the presence of radiation, provides by either direct or indirect means a signal or other indication suitable for use in measuring one or more quantities of the incident radiation

Note 1 to entry: The detector usually requires a separate reader to read out the signal. That means the detector usually is not able to provide a signal without any external reading process.

Note 2 to entry: A passive detector does not need an external power supply to collect and store dose information.

Note 3 to entry: In IEV, the term reads “radiation detector”.

[SOURCE: IEC 60050-881:1983, 881-13-01, modified – The term “detector” has been added as the first preferred term]

3.9
deviation
D
difference between the indicated values for the same value of the measurand of a dosimetry system, when an influence quantity assumes, successively, two different values

$$D = G - G_r$$

where

G the indicated value under the effect, and

G_r the indicated value under reference conditions

Note 1 to entry: The original term in IEV 311-07-03 reads “variation (due to an influence quantity)”. In order not to mix up variation (of the indicated value) and variation of the response, in this standard, the term is called “deviation”.

Note 2 to entry: The deviation can be positive or negative resulting in an increase or a decrease of the indicated value, respectively.

[SOURCE: IEC 60050-300-311:2001, 311-07-03, modified – "deviation" has replaced “variation (due to an influence quantity)” and “dosimetry system” has replaced “an indicating measuring instrument, or the values of a material measure” and Notes 1 and 2 to entry have been added]

3.10
directional dose equivalent
$H'(d)$
at a point in a radiation field, dose equivalent that would be produced by the corresponding expanded field, in the ICRU sphere at a depth, d, on the radius in a specified direction

Note 1 to entry: The currently recommended depth, d, for environmental monitoring with respect to local skin and lens of the eye is 0,07 mm and 3 mm, respectively, and $H'(d)$ may be written as $H'(0,07)$and $H'(3)$, respectively.

[SOURCE: ICRU 51:1993, modified – Note 1 to entry has been added]

3.11
dosemeter
radiation meter designed to measure quantities such as an absorbed dose or dose equivalent

Note 1 to entry: In a wider sense, this term is used for meters designed to measure other quantities related to radiation such as exposure, fluence, etc. Such use is deprecated.

Note 2 to entry: This apparatus may require a separate reader to read out the absorbed dose or dose equivalent.

Note 3 to entry: A dosemeter usually consists of a detector and a badge, for example thermoluminescence detector (TLD) badge with filters.

Note 4 to entry: A dosemeter may contain electronic components (e.g. for the readout (e.g. in a direct ion storage (DIS) dosemeter)).

[SOURCE: IEC 60050-395:2014, 395-05-02, modified – Notes 3 and 4 to entry have been added]

3.12
dosimetry system
dosemeter, reader and all associated equipment and procedures used for assessing the indicated value

3.13
expanded uncertainty
U
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: The expanded uncertainty is obtained by multiplying the combined standard uncertainty by a coverage factor.

Note 2 to entry: A confidence level of 95 % is recommended for the use of this document.

[SOURCE: GUM:1995, 2.3.5]

3.14
indicated value
indication
G
value of the measurand given directly by a measuring instrument on the basis of its calibration curve

Note 1 to entry: In this standard, the indicated value is the one given by the dosimetry systems as the final result of the evaluation algorithm (for example, display of the software, print out) in units of dose equivalent (Sv), see 8.2.

Note 2 to entry: For details, see Annex B.

[SOURCE: IEC 60050-300-311:2001, 311-01-08, modified – The original note has been replaced by new Notes 1, 2 and 3 to entry]

3.15
influence quantity
quantity that is not the measurand but that affects the result of the measurement

Note 1 to entry: For example, temperature of a length measuring instrument.

Note 2 to entry: If the effect on the result of a measurement of an influence quantity depends on another influence quantity, these influence quantities are treated as a single one. In this standard, this is the case for two pairs of influence quantities:

a) radiation energy and angle of incidence,

b) ambient temperature and relative humidity.

[SOURCE: GUM:1995, B.2.10, modified – Examples 1, 2 and 3 have been removed and Notes 1 and 2 to entry have been added]

3.16
influence quantity of type F
influence quantity whose effect on the indicated value is a change in response

Note 1 to entry: An example is radiation energy and angle of radiation incidence.

Note 2 to entry: F stands for factor. The indication due to radiation is multiplied by a factor due to the influence quantity.

3.17
influence quantity of type S
influence quantity whose effect on the indicated value is a deviation independent of the indicated value

Note 1 to entry: An example is the electromagnetic disturbance.

Note 2 to entry: All requirements for influence quantities of type S are given with respect to the value of the deviation D.

Note 3 to entry: S stands for sum. The indication is the sum of the indication due to radiation and due to the disturbance.

3.18
instrument constant
c_i
constant by which the indication of the dosemeter G or – if corrections or a normalization were applied – the corrected indication $G_{r,0}$ is multiplied to convert it to the same unit as the measurand

Note 1 to entry: Adapted from ICRU Report 76.

Note 2 to entry: If the instrument's indication is already expressed in the same unit as the measurand the instrument constant, c_i, is unnecessary. This is the case in this standard.

[SOURCE: ISO 29661:2012, 3.1.17]

3.19
lower limit of the measuring range
H_{low}
lowest dose value included in the measuring range

Note 1 to entry: H_{low} is equivalent to H_0 in ISO 14146:2018.

3.20
mandatory range
mandatory range of use
smallest range specified for an influence quantity or instrument parameter over which the dosimetry system must operate to be in compliance with this document

Note 1 to entry: The mandatory ranges of the influence quantities dealt with in this document are given in the second column of Table 8 to Table 16.

3.21
maximum rated measurement time
t_{max}
longest continuous period of time over which the dose is accumulated and over which all requirements of this document are fulfilled

Note 1 to entry: The maximum rated measurement time depends on the lower limit of the measuring range H_{low}, the fading, and other influences.

Note 2 to entry: The beginning of this period of time can for example be erasing the dose by heating (for TLDs) or a dose reset by means of software (for DIS).

3.22
measured value
M
value that can be obtained from the indicated value G by applying the model function for the measurement

Note 1 to entry: For “model function”, see 3.25.

Note 2 to entry: For details, see Annex B.

3.23
measuring range
range defined by two values of the measurand, or quantity to be supplied, within which the limits of uncertainty of the measuring instrument are specified

Note 1 to entry: In this standard, the measuring range is the range of dose equivalent, in which the requirements of this standard are fulfilled and thus the uncertainty is limited.

[SOURCE: IEC 60050-300-311:2001, 311-03-12, modified – The original note has been replaced by a new Note 1 to entry]

3.24
personal dose equivalent
$H_p(d)$
dose equivalent in soft tissue, at an appropriate depth, d, below a specified point on the body

Note 1 to entry: The recommended depths are 10 mm for penetrating radiation, 3 mm to monitor the eye lens dose, and 0,07 mm to monitor skin dose.

Note 2 to entry: Soft tissue means ICRU 4-element tissue, see ICRU Report 39.

[SOURCE: ICRU 51:1993, modified – Notes 1 and 2 to entry have been added]

3.25
model function
mathematical model of the measurement that transforms the (set of) observation(s) into the result of the measurement

Note 1 to entry: The model function combines the indicated value G with the reference calibration coefficient N_0, the correction for non-linearity r_n, the l deviations D_p (p = 1..l) for the influence quantities of type S, and the m relative response values r_q (q = 1..m) for the influence quantities of type F. An example of a model function is

$$M = \frac{N_0}{r_n \prod_{q=1}^{m} r_q} \left[G - \sum_{p=1}^{l} D_p \right].$$

A model function is necessary to evaluate the uncertainty of the measured value according to the GUM (see GUM:1995, 3.1.6, 3.4.1 and 4.1).

Note 2 to entry: The calculations according to the model function are usually not performed, only in the case that specific influence quantities are well known and an appropriate correction is applied.

Note 3 to entry: For details, see Annex B.

3.26
point of test
point in the radiation field at which the conventional quantity value of the quantity to be measured is known

[SOURCE: ISO 29661:2012, 3.1.23, modified – “to be measured” has been added]

3.27
preparation
normal treatment of dosemeters or detectors before a dose measurement, which the dosemeters or detectors are intended to be subjected to in routine use

Note 1 to entry: For example, a procedure to erase stored dose information, reset the dose information by means of software, cleaning.

3.28
rated range
rated range of use
specified range of values which an influence quantity can assume without causing a deviation or variation of the response exceeding specified limits

Note 1 to entry: In IEC 60050-300-311:2001, 311-07-05, the term reads “nominal range of use”. In this document, “rated range” is used in order to avoid complicated terms like “the range of use of an influence quantity” but to have terms that are easily readable like “the rated range of an influence quantity”.

Note 2 to entry: Influence quantities can be either of type S or of type F.

[SOURCE: IEC 60050-300-311:2001, 311-07-05, modified – “rated range” has replaced “nominal range” and “deviation or variation of the response” has replaced “variation”; Notes 1 and 2 to entry have been added]

3.29
reader
dosemeter reader
instrument used to read one or more detectors in a dosemeter

Note 1 to entry: Signal of a passive dosemeter can be amount of light, amount of charge, transparency of film and so on. Each type of passive dosemeter thus has very a different type of reader.

Note 2 to entry: The readout can also be taken over by self-reading components of the dosemeter, e.g. within DIS dosemeters.

3.30
readout
process of measuring the stored dose information of a detector in a reader

Note 1 to entry: If the dosemeter contains self-reading components, e.g. DIS dosemeters, the resulting signal may be corrected for influences such as temperature, fading, etc.

3.31
reference conditions
set of specified values and/or ranges of values of influence quantities under which the uncertainties admissible for a dosimetry system are the smallest

[SOURCE: IEC 60050-300-311:2001, 311-06-02, modified – After “uncertainties” the words “, or limits of error,” have been deleted and “dosimetry system” has replaced “measuring instrument”]

3.32
reference direction
direction, in the coordinate system of a dosemeter, with respect to which the angle to the direction of radiation incidence is measured in unidirectional fields

[SOURCE: ISO 29661:2012, 3.1.29]

3.33
reference orientation
(dosemeter) orientation for which the direction of the incident radiation coincides with the reference direction of the dosemeter

[SOURCE: ISO 29661:2012, 3.1.31]

3.34
reference point of a dosemeter
physical mark or marks on the outside of the dosemeter (possibly described in the manual) to be used in order to position it with respect to the point of test; if there is no mark or marks on the outside of the dosemeter, the geometric centre of the dosemeter should be taken as the reference point

3.35
reference response
R_0
response for a reference value $C_{r,0}$ of the quantity to be measured under reference conditions

$$R_0 = \frac{G_{r,0}}{C_{r,0}}$$

where $G_{r,0}$ is the corresponding indicated value

Note 1 to entry: The reference response is the reciprocal of the reference calibration coefficient.

Note 2 to entry: The reference values for the dose are given in Table 7.

3.36
relative expanded uncertainty
U_{rel}
expanded uncertainty divided by the measurement result

3.37
relative response
r
quotient of the response R and the reference response R_0

$$r = \frac{R}{R_0}$$

3.38
response of a radiation measuring assembly
R
ratio, under specified conditions, given by the relation:

$$R = \frac{G}{C}$$

where

G is the indicated value of the quantity measured by the equipment or assembly under test (dosimetry system), and

C is the conventional quantity value of this quantity

Note 1 to entry: The value of the response may vary with the dose being measured. In such cases, a dosimetry system is said to be non-linear.

[SOURCE: IEC 60050-395:2014, 395-03-72, modified – The letters representing quantities have been modified, “value” has been replaced by “indicated value of the quantity”, “(dosimetry system)” has been added and the original notes have been replaced by a new Note 1 to entry]

3.39
result of a measurement
set of values attributed to a measurand, including a value, the corresponding uncertainty, and the unit of the measurand

Note 1 to entry: The central value of the whole (set of values) can be selected as *measured value* M (see 3.22) and a parameter characterizing the dispersion as *uncertainty* (see 3.43).

Note 2 to entry: The result of a measurement is related to the *indicated value given by the instrument* G (see 3.14) and to the values of correction obtained by calibration and by the use of a *model* (see 3.25).

Note 3 to entry: The estimation of M can be based on one or more indicated values.

[SOURCE: IEC 60050-300-311: 2001, 311-01-01, modified – "including a value, the corresponding uncertainty, and the unit of the measurand" has been added, the original Notes 1, 4, and 5 have been deleted, and Notes 1 and 2 to entry have been aligned to terms used in this document]

3.40
signal
S
quantity obtained in a reader after readout of a detector from which the indicated value of the dose equivalent is evaluated

Note 1 to entry: Examples are the charge measured in a photomultiplier tube due to TL-light; the area of a certain region from a glow curve of a TL detector; a fitting parameter evaluated from a glow curve analysis.

Note 2 to entry: In principle, it is possible to obtain more than one signal from one detector (for example several fitting parameters from a glow curve analysis).

Note 3 to entry: Using more than one detector always means using more than one signal.

Note 4 to entry: The "signal" is similar to the "readout value" in ISO 12794:2000, 3.13.

Note 5 to entry: For details, see Annex B.

3.41
standard deviation
experimental standard deviation
s
for a series of n measurements of the same measurand, the quantity s characterizing the dispersion of the results

$$s = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(G_j - \overline{G}\right)^2}$$

where

G_j is the result of the j-th measurement, and

$\overline{G}$ is the arithmetic mean of the n results considered

Note 1 to entry: Considering the series of n values as sample of a distribution, $\overline{G}$ is an unbiased estimate of the mean μ, and s^2 is an unbiased estimate of the variance σ^2 of that distribution.

Note 2 to entry: The expression $s/\sqrt{n}$ is an estimate of the standard deviation of the distribution of $\overline{G}$ and is called the "experimental standard deviation of the mean".

Note 3 to entry: "Experimental standard deviation of the mean" is sometimes incorrectly called "standard error of the mean".

[SOURCE: GUM:1995, B.2.17, modified – The preferred term "standard deviation" has been added, as well as the symbol s, and the formula has been modified]

3.42
standard test conditions
conditions represented by the range of values of a set of influence quantities under which a calibration or a determination of response is carried out

Note 1 to entry: Appropriate corrections to reference conditions should be made.

Note 2 to entry: Ideally, calibrations should be carried out under reference conditions. As this is not always achievable (e.g. for ambient air pressure) or convenient (e.g. for ambient temperature) a (small) interval around the reference values is acceptable. Values for the standard test conditions together with the reference conditions are given in Table 7.

Note 3 to entry: During type tests, all values of influence quantities which are not the subject of the test are fixed within the interval of the standard test conditions.

[SOURCE: ISO 29661:2012, 3.1.36, modified – Note 3 to entry has been added]

3.43
standard uncertainty
u
uncertainty of the result of a measurement expressed as a standard deviation

Note 1 to entry: Standard uncertainty is a more general term than standard deviation, for example, standard uncertainty may also contain uncertainty contributions evaluated using non statistical methods.

[SOURCE: GUM 2.3.1, modified – Note 1 to entry has been added, as well as the symbol u]

3.44
type test
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16]

3.45
upper limit of the measuring range
H_{up}
highest dose value included in the measuring range

3.46
area monitoring
monitoring in which a workplace or an area in the environment is monitored by taking dose (rate) measurements

Note 1 to entry: Area monitoring is performed in terms of $H'(0,07)$, $H'(3)$ or $H^*(10)$.

Note 2 to entry: Definition orientated at ICRP 103 and ICRP 116.

3.47
workplace monitoring
area monitoring using dose (rate) measurements made in the working environment

Note 1 to entry: Usually contrasted with individual monitoring.

Note 2 to entry: Workplace monitoring is performed in terms of $H'(0,07)$, $H'(3)$ or $H^*(10)$.

3.48
environmental monitoring
area monitoring by the measurement of external dose (rate) in the environment

Note 1 to entry: Environmental monitoring is performed in terms of $H'(0,07)$, $H'(3)$ or $H^*(10)$.

3.49
individual monitoring
monitoring using dose (rate) measurements by equipment worn by individual workers, or measurements of quantities of radioactive material in or on their bodies

Note 1 to entry: Also called personal monitoring. Usually contrasted with workplace monitoring.

Note 2 to entry: Individual monitoring is performed in terms of $H_p(0,07)$, $H_p(3)$ or $H_p(10)$.

[SOURCE: IAEA Glossary:2016, modified – “dose (rate)” has been added and Note 2 to entry has been added]

4 Units and symbols

In this document, units of the international system (SI) are used. Nevertheless, the following units may be acceptable in common usage:

– for energy: electron-volt (symbol eV). 1 eV = 1,602 × 10^{-19} J;
– for time: year, month, day, hour (symbol h), minute (symbol min).

Multiples and submultiples of SI units may be used, according to the SI system.

The SI unit of dose equivalent is 1 J kg^{-1}.

The special name for the unit of the dose equivalent is sievert (symbol Sv). 1 Sv = 1 J kg^{-1}.

A list of symbols is given in Table 6.

A list of abbreviations is given in Table 17.

5 General test procedures

5.1 Basic test procedures

5.1.1 Instructions for use

The instructions for use of the dosimetry systems have to be unambiguously given in the manual, see Clause 9. These instructions have to be the same for all parts of the type test and for the routine use as well.

5.1.2 Nature of tests

The tests listed in this document are considered to be type tests, see Annex C.

5.1.3 Reference conditions and standard test conditions

Reference conditions are given in the second column of Table 7 (at the end of the document). The tests shall be carried out under standard test conditions given in the third column of Table 7 unless otherwise specified.

All influence quantities shall be maintained within the limits set for standard test conditions given in Table 7, except for those influence quantities currently under test, unless otherwise specified in the test procedure.

5.1.4 Production of reference radiation

The nature, construction and conditions for the use of ionizing radiation shall conform to the recommendations in the following documents:

a) ISO 4037 series for photon radiation,
b) ISO 6980 series for beta radiation, and
c) ISO 8529 series for neutron radiation.

5.1.5 Choice of phantom for the purpose of testing

For tests involving the use of a phantom, ISO phantoms as described in ISO 4037-3:2019, 7.3.1, shall be used. The required irradiation geometry is specified in the appropriate ISO reference standard (ISO 4037-3 or ISO 6980-3).

5.1.6 Position of dosemeter for the purpose of testing

For tests involving the use of radiation, the reference point of the dosemeter shall be placed at the point of test and the dosemeter shall be oriented in the reference orientation. This is not applicable for tests to determine the response depending on the angle of incidence.

5.2 Test procedures to be considered for every test

5.2.1 Number of dosemeters used for each test

The number n of dosemeters (or irradiations) used for any test need not be the same for each test but may be determined using Annex A. However, it may be convenient to use, arbitrarily, 4, 5, 8, 10 or 20 dosemeters (or irradiations), in which case the Student's t-value, obtained from Annex A, Table A.1, would be 3,18; 2,78; 2,37; 2,26; or 2,09; respectively.

NOTE Using Annex A, the performance requirements are demonstrated to be met to 95 % confidence.

5.2.2 Consideration of the uncertainty of the conventional quantity value

The relative expanded uncertainty $U_{C,\mathrm{rel}}$ of the conventional quantity value C of the dose equivalent shall be considered. It shall be less than 8 % at a 95 % coverage interval. The testing laboratory shall determine $U_{C,\mathrm{rel}}$ according to the GUM.

NOTE According to 3.13, the confidence level is 95 %.

5.2.3 Consideration of non-linearity

The effect of a non-linearity due to dose dependence shall be taken into account.

A practical method is to start the tests with the non-linearity and perform the other tests in a dose region where the non-linearity is negligible (1 % to 2 %).

5.2.4 Consideration of natural background radiation

For the measurement of low dose equivalents or at low dose equivalent rates, it is necessary to take into account the contribution of natural background radiation to the dose equivalent. This is usually done by taking a significant number of dosemeters (at minimum 10 dosemeters) as background dosemeters. These are treated in the same way as the ones under test, but not irradiated. The mean indicated value of these dosemeters has to be subtracted from the indicated value of the dosemeters under test.

5.2.5 Consideration of several detectors or signals in a dosemeter

If more than one signal (see 3.40) or detector (see 3.8) is used to evaluate the indicated value, each signal or detector shall be tested separately. Separate tests are necessary when the different signals are used to evaluate the indicated value in different regions of the measuring range or in different regions of an influence quantity.

NOTE If this applies, this means that the complete amount of testing according to this document is multiplied by the number of signals being used in different ranges.

EXAMPLE 1 If a second detector or signal is used to evaluate the dose above a dose equivalent of 200 mSv, for this detector or signal all the requirements according to this document have to be measured within its operating range, i.e. above a dose equivalent of 200 mSv.

EXAMPLE 2 If a second detector or signal is used to evaluate the dose at very low particle energies (for example a very thin detector for low energy beta radiation), for this detector or signal all the requirements according to this document have to be measured within its operating range, i.e. at low particle energies.

5.2.6 Performing the tests efficiently

The effect of several influence quantities is tested by irradiating different groups of dosemeters: one or several test groups on which the effect of the influence quantity is measured and one reference group. For limiting the necessary number of irradiations, it is appropriate to combine the tests given in 11.9 to Clause 15 with only two or three reference groups.

A list of actions necessary to perform a type test according to this document is given in Annex C.

6 Performance requirements: summary

For the following types of dosemeters at least the following quantities shall be measured:

- personal whole body dosemeters: $H_p(10)$ due to photon radiation,
- personal eye lens dosemeters used in pure photon radiation fields: $H_p(0{,}07)$ or $H_p(3)$ due to photon radiation,
- personal eye lens dosemeters used in beta and/or mixed beta/photon radiation fields: $H_p(3)$ due to beta and photon radiation,
- personal extremity dosemeters: $H_p(0{,}07)$ due to photon and/or beta radiation,
- area dosemeters for estimating effective dose: $H^*(10)$ due to photon radiation,
- area dosemeters for estimating the dose to the lens of the eye used in pure photon radiation fields: $H'(0{,}07)$ or $H'(3)$ due to photon radiation,
- area dosemeters for estimating the dose to the lens of the eye used in beta and/or mixed beta/photon radiation fields: $H'(3)$ due to beta and photon radiation,
- area dosemeters for estimating the dose to local skin: $H'(0{,}07)$ due to photon radiation.

National regulations may require that more quantities be measured by specific types of dosemeters.

NOTE 1 Background information regarding the choice of quantities to be measured for eye lens dosimetry can be found in Behrens and Dietze (2010).

NOTE 2 The term “beta radiation” is used as a synonym for both electron and beta radiation in this document.

The performance requirements for dosimetry systems are given in Tables 8 to 13 depending on the quantity to be measured: $H_p(10)$: Table 8; $H_p(3)$: Table 9; $H_p(0{,}07)$: Table 10; $H^*(10)$: Table 11; $H'(3)$: Table 12; $H'(0{,}07)$: Table 13.

Details for some of the entries in Tables 8 to 13 (at the end of the document) are given in the further Tables 14 to 16 (at the end of the document).

In some countries the presence of beta dose has to be indicated by dosemeters worn on the trunk. Such an indication of the presence of beta dose is not a measurement. For that reason, a specific subclause (11.9) deals with the indication of the presence of beta dose.

Usually, a dosimetry system is not able to measure all quantities given above. Thus, the system is only tested with regard to those quantities and types of radiation it is intended to be used for.

Full compliance with this document is given if the requirements for the mandatory ranges given in Tables 8 to 13 are fulfilled. If the customer or manufacturer requires extended ranges then the test should also be performed as specified in this document, i.e. the requirements given in Tables 8 to 13 apply, too. The range of any influence quantity stated by the manufacturer is called rated range. Thus, dosimetry systems can be classified by stating a set of ranges (for example, for dose, for energy, for temperature) within which the requirements stated in this document are met (Capabilities of the system, see Clause 7).

For the dosimetry systems described above, this document specifies general characteristics, general test procedures and performance requirements, radiation characteristics as well as environmental, electrical, mechanical, software and safety characteristics.

A dosimetry system may be tested with regard to different quantities at different times. In case the dosimetry system was changed since the previous test, a new test with regard to quantities tested formerly may be necessary.

The absolute calibration of the dosimetry system is not checked during a type test according to this document as only system properties are of interest. The absolute calibration is checked during a routine test.

7 Capability of a dosimetry system

7.1 General

The ranges described in the following subclauses shall be stated by the manufacturer. They shall be equivalent to or larger than the mandatory ranges that are given in Table 8 to Table 13. The dosimetry system shall fulfil the requirements for these rated ranges.

The rated ranges shall be given in the documentation of the dosimetry system (instruction manual), so the user of the dosimetry system is aware of the capabilities of the instrument.

7.2 Measuring range and type of radiation

Depending on the dose quantity, the limits of the measuring range shall at least cover the mandatory ranges given in line 7 of Table 8 to Table 13.

The type(s) of radiation the dosimetry system is designed for shall be stated.

In case the dosimetry system is not able to measure $H_p(0,07)$ due to beta radiation due to all required energies and angles of incidence (that means it does not fulfil 11.7.2) but is able to indicate the presence of beta dose (that means it does fulfil 11.9) this shall be stated.

7.3 Rated ranges of the influence quantities

The rated range of any influence quantity shall be stated by the manufacturer in the documentation. The mandatory range for each influence quantity is given in the third column of Table 8 to Table 16. All requirements of this document shall be fulfilled over all the rated ranges.

7.4 Maximum rated measurement time t_{max}

The manufacturer shall state the maximum duration of a dose measurement t_{max} during which the requirements of this document are fulfilled. Especially, the requirements on the coefficient of variation shall be fulfilled.

This time shall be at least 1 month.

7.5 Reusability

A dosemeter is considered to be reusable as long as its performance meets the requirements of this document. If the dosemeter cannot be reused indefinitely or if usability depends on the history of the dosemeter, this fact shall be stated by the manufacturer. The manufacturer shall give the limits for repeated uses, i.e. a maximum dose value to which the dosemeter was exposed above which it cannot be reused. Especially, the requirements related to the coefficient of variation shall be fulfilled for all dosemeters that are reused.

NOTE An example of limited reusability is an increase of the zero-signal in a TL detector after receiving a high dose.

7.6 Model function

The manufacturer shall state the general form of the model function for the measurement with the dosemeter. The manufacturer can use the example given in 3.25 or other functions. The manufacturer shall state any interdependencies between the variables of the model function. The variables are the calibration coefficient, the relative responses, and the deviations.

NOTE Further details regarding the model function and the determination of uncertainty in measurement are given in IEC TR 62461.

7.7 Example for the capabilities of a dosimetry system

The following numbers are arbitrarily chosen, covering at least the mandatory ranges, and differ from one dosimetry system to another.

The dosimetry system can be used to measure $H_p(10)$ due to photon radiation:

Measuring range: 0,05 mSv $\leq H_p(10) \leq$ 4 Sv. The dosimetry system is able to indicate the presence of beta dose.

The following ranges of use for the different influence quantities are covered.

- Photon energy and angle of incidence: 50 keV to 1,4 MeV and 0° to ± 60°
- Ambient temperature and relative humidity (dosemeters): –15 °C to 50 °C and 40 % to 90 % RH
- Ambient temperature (reader): +10 °C to +40 °C
- Light exposure (dosemeters and reader): up to 1 000 W/m^2
- Electromagnetic disturbances (reader): mandatory ranges, see Table 15
- Mechanical disturbances: mandatory ranges, see Table 16

Maximum rated measurement time: 6 months.

The dosemeters of the dosimetry system are reusable unless irradiated with a dose equivalent exceeding 200 mSv.

Model function: $M = \frac{N_0}{r_n \cdot r_{E,\alpha} \cdot r_{env}} \cdot [G - D_{EMC} - D_{mech}]$

where

M is the measured value;

N_0 is the reference calibration coefficient;

r_n is the relative response due to non-linearity;

$r_{E,\alpha}$ is the relative response due to energy and angle of incidence;

r_{env} is the relative response due to environmental influences;

G is the indicated value of the dosimetry system;

D_{EMC} is the deviation due to electromagnetic disturbances;

D_{mech} is the deviation due to mechanical disturbances.

For details see 3.22 and Annex B.

8 Requirements for the design of the dosimetry system

8.1 General

The information required in this Clause 8 shall be documented by the manufacturer for the type test in written form (not necessarily in the instruction manual). The requirements given can easily be checked by visual inspection of the dosimetry system during use.

8.2 Indication of the dose value (dosimetry system)

The indicated value shall be given in units of dose equivalent, for example, microsieverts (μSv). The display or dose record shall also clearly indicate the quantity being measured.

If the reader has range-change facilities, the range-change shall be automatic.

At dose values equal to or larger than ten times the lower limit of the measuring range, i.e. at $H \geq 10 \cdot H_{\text{low}}$, the indicated value shall be displayed with a resolution better than 2 %. At the lower limit of the measuring range, H_{low}, a value of 10 % is sufficient.

NOTE A possible technical solution is a digital display: at the lower limit of the measuring range, H_{low}, at least two significant digits are shown. For example, at H_{low} = 0,1 mSv the display shows 0,10 mSv. Above $10 \cdot H_{\text{low}}$, three significant digits are shown: 1,00 mSv.

8.3 Assignment of the dose value to the dosemeter (dosimetry system)

Every indicated value shall be distinctively assigned to the dosemeter (number) it is originating from.

NOTE A possible technical solution is: the assignment during unpacking detectors from their dosemeter is done very carefully. After data evaluation, the dosemeter number and the indicated value are combined into one data set that is always handled together.

8.4 Information given on the devices (reader and dosemeter)

The following information shall be clearly visible on the reader, a) to d), and on the dosemeter, a) to g), if enough space is available on the dosemeter:

a) an identification to assign the reader and dosemeter to the dosimetry system;

b) the quantity and measuring range that is measured;

c) the type of radiation (for example photon and / or beta) the dosemeter is suitable for;

d) the rated range of particle energy;

e) only on personal dosemeters: if it is possible to wear the dosemeter in two or more orientations, then the dosemeter shall fulfil the requirements of this document for all orientations or it shall clearly be stated on the dosemeter which orientation is correct or that using it in the wrong orientation can cause erroneous results;

f) only on the dosemeter: the reference point and reference orientation (or in the manual);

g) only on the dosemeter: an identification number that can be read by the user (mandatory).

NOTE An example for b) to d) is: 0,1 mSv ≤ $H_p(0,07)$ ≤ 3 Sv; 65 keV ≤ E_{ph} ≤ 1,4 MeV; 0,24 MeV ≤ E_{beta} ≤ 0,8 MeV.

8.5 Retention and removal of radioactive contamination (dosemeter)

As far as reasonably practical, the dosemeter should be designed to minimize the retention and facilitate the removal of contamination. A dosemeter may be provided with an additional protective cover, however, the covered dosemeter shall still meet the requirements of this document.

8.6 Algorithm to evaluate the indicated value (dosimetry system)

For the type test according to this document, the manufacturer shall deliver the evaluation algorithm of the indicated value starting from the signal(s) of the detector(s). The documentation shall be in a form that allows a complete understanding of the calculations and/or the decision tree.

If more than one signal is used to evaluate the indicated value, the manufacturer shall provide the option of reading out the separate signals of the detector(s) for the type test.

NOTE Details to signal, evaluated value and evaluation algorithm are given in Annex B.

This algorithm can be confidential and only be used by the testing laboratory for the purpose of type testing.

8.7 Use of dosemeters in mixed radiation fields (dosimetry system)

If a dosemeter is used in radiation fields for which it is not designed, an example is a photon dosemeter being used in a mixed photon/neutron field, the effect of the radiation not intended to be measured shall be stated by the manufacturer in the manual, see Clause 9. In the mentioned example, the neutron radiation is an influence quantity for the dosemeter designed for photon radiation. The manufacturer shall state the response to neutron radiation for thermal neutrons and one or more of the ISO 8529 radionuclide source reference fields.

With this information, the user can determine the influence on the total dose value with the aid of a second dosemeter intended to measure the neutron radiation.

9 Instruction manual

9.1 General

An instruction manual shall be supplied. It shall be marked in such a way that it is unambiguously related to the dosimetry system described. Such instructions for use are to be furnished for each dosimetry system. The instructions for use shall contain the description of the construction, function, operation and manipulation of the dosimetry system and its component parts including the usage of the software used to control the dosimetry system and the stored data.

9.2 Specification of the technical data

Dosimetry system in general:

– manufacturer's name or registered trade mark (if the system is manufactured as a whole);
– type of dosimetry system and principle of operation;
– block diagram of the dosimetry system including hardware, software and data;
– name of the software of the dosimetry system and identification number (see 10.3);
– description of the functionality and all menus and submenus of the software;

– operational details, maintenance and calibration procedures;
– if the evaluation algorithm is not additive, a comment according to Note 3 of 12.1.

Reader:

– manufacturer's name or registered trade mark;
– type of the reader;
– power supply requirements;
– stabilization time of the reader;
– hint to the necessity of flushing the dosemeter or parts of it with gas during readout;
– warning if prolonged storage at high humidity of the air can be detrimental.

Dosemeter:

– manufacturer's name or registered trade mark;
– type of dosemeter;
– type of detector or detectors;
– types of radiation the dosemeter is intended to measure;
– reference point of the dosemeter;
– the reference direction for calibration purposes;
– reference orientation relative to radiation sources and reference orientation with respect to the wearer;
– drawing of the dosemeters including the detectors and filter materials;
– density thickness of walls surrounding the sensitive volumes (mg cm^{-2});
– mass and dimensions of dosemeter;
– method of cleaning and drying the dosemeter;
– method of clearing dose (“zeroing”) of dosemeter.

Dosimetric characteristics:

– measuring quantity;
– measuring range and variation of the response due to non-linearity;
– coefficient of variation depending on the dose equivalent;
– maximum rated measurement time;
– response to natural environmental radiation, see 13.4;
– relative response as a function of radiation energy and angle of incidence (for both beta and photon radiation);
– rated ranges of all other influence quantities and the corresponding variation of the relative response or deviation (see 7.2 to 7.6, an example is given in 7.7);
– relative response due to radiation not intended to be measured (for example neutron radiation), see 8.7;

10 Software, data and interfaces of the dosimetry system

10.1 General

The final version of the software shall be available at the beginning of the type test, as a great part of the software test is indirectly covered by the metrological test. For that reason, a change of the data-relevant part of the software after the type test is not permitted (for data-relevant part see below).

NOTE The following requirements are based on the software guide 7.2 of the European cooperation in legal metrology (WELMEC) and are implementing risk class C of guide 7.2. The WELMEC guide can serve as additional information, however, only the requirements given in this Clause 10 are relevant.

The requirements shall prevent any unintended modification of the software or of the data. In addition, any intended modification of the software or of the data with the aid of an editor shall be prevented. At most, one indicated value may be lost due to any change of the software or data.

The requirements are to be applied only when the dosimetry system is used for official purposes, for example, legally required personal monitoring.

Once the type test according to this document has been started, no data, tables, or software may be changed or deleted.

Testing of the data-relevant part of the software can be a very complex matter. However, it shall not dominate the testing-time. Therefore, a large amount of responsibility is handed over to the manufacturer by using his documentation, see 10.10, to perform the tests. Nevertheless, a few simple practical tests are made to make sure that the functionality is as documented.

10.2 Design and structure of the software

10.2.1 Requirements

The software shall be designed in such a way that it is not affected by other software unless the effect is required for the correct use of the system.

NOTE One possible technical solution is to separate the software into two parts. One part contains all the functions necessary to control the reader and to evaluate, store and display the indicated values, this part is the “data-relevant part”. The other parts of the software, the “non-data-relevant part”, contain for example statistics about the frequency with which certain dose values occur. The data-relevant part has well-defined functions (software interface) that are used to communicate with the non-data-relevant software parts. This technical concept of software separation has the advantage, that the “non-data-relevant part” may be modified without influencing the “data-relevant part”.

10.2.2 Method of test

Documentation: The measures described to protect the software shall be plausible taking into account the type of operating system on the computer.

Practical test: Make sure that the software is an executable file. In case of software separation, see the note to 10.2.1, the different software parts shall be separate files (for example dynamic link libraries (DLLs)).

10.3 Identification of the software

10.3.1 Requirements

The “data-relevant part” of the software (see Note to 10.2.1) shall have an identification. It shall be possible to display this identification while the software is running. This identification can be compared with the one given in the test record or in the user instructions. The identification shall automatically change in case the software is changed (a simple version number is not sufficient).

NOTE 1 In case of a modular code, several identifications can be built for the different modules.

NOTE 2 One possible technical solution is a checksum, at least cyclic redundancy check using a polynomial lengths of 17 bits (CRC-16) with a secret start value hidden in the executable file, built over the software.

10.3.2 Method of test

Documentation: The method to make sure that the software identification is changed by any modification of the software shall be plausible.

Practical test: Make sure that the identifications can be displayed while the software is running as described in the instruction manual and that they are identical to the ones given in the instruction manual.

10.4 Authenticity of the software and the presentation of results

10.4.1 Requirements

Protection shall cover both, unintentional actions (inadvertent wrong operation) and intended actions (manipulation) by means of an editor. In case the software is modified, the program shall abort during start up with a message such as “Software authenticity violated; unauthorized modification of program!”. The results that are presented shall be guaranteed as authentic, clearly marked as relevant result of the measurement, and clearly separated from additional information.

This requirement is to prevent the reader or dosemeter being operated with software other than the type tested version.

NOTE One possible technical solution is:

The program code is an executable format (.exe). During start-up of the software, a digital signature is checked. In case of non-compliance, the software does not start. The window of the running program is refreshed periodically and checks that it is always visible.

10.4.2 Method of test

Documentation: The measures to prevent any change of the software (for example the evaluation of a checksum) shall be plausible. Check that the legally relevant data sets can only be produced by the type tested data-relevant software.

Practical test: Modify a string value (for example “µSv” into “mSv”) in the executable code with the aid of an editor and run the software. If it starts, the requirement is not met. Judge through visual check that additional information on the display or printout cannot be confused with the information belonging to the relevant measurement data and that all relevant data are presented.

10.5 Alarm and stop of system operation under abnormal operating conditions

10.5.1 Requirements

When abnormal operating conditions occur in system components, the operation of the dosimetry system shall be stopped automatically, in addition an alarm alerting the operator shall be present (audible and/or visible). These abnormal operating conditions include those that lead to a faulty reading or loss of dose information, for example, high voltage failure in a photomultiplier tube, a printer running out of paper, heating temperature in a reader falling below or rising above the normal range of operating temperature, a wireless local area network (WLAN) getting out of range, or if the software controlling the measurement is stopped.

Not more than one indicated value shall be lost due to abnormal operating conditions. In case an indicated value does not fulfil the requirements of this document due to the abnormal operating conditions, this value shall be accompanied by an error message. At maximum one value shall be accepted to be wrong per occurrence of abnormal operating condition if a re-evaluation of the dosemeter is not possible. If a re-evaluation is possible the new indicated value shall fulfil the requirements of this document.

10.5.2 Method of test

Documentation: The measures to recognize faulty operation shall be plausible.

Practical test: Simulate some hardware failures during the readout, for example disconnect the power supply for the heating device, put a wireless local area network (WLAN) out of range, or disconnect the data line between the reader and the computer. If more than one indicated value per simulated hardware failure is lost or accompanied by an error message due to the abnormal operating condition, the requirement is not met. If a re-evaluation is possible the new indicated value shall fulfil the requirements of this document.

10.6 Control of input data by the dosimetry system

10.6.1 Requirements

All values used for the determination of the indicated value, for example calibration coefficients, dark-current of a photomultiplier or high voltage of a photomultiplier shall be controlled by the dosimetry system.

NOTE One possible technical solution is to ensure that these values fall within fixed ranges of values.

10.6.2 Method of test

Documentation: The method to make sure that the instrument parameters are in their allowed ranges shall be plausible.

Practical test: Try to change some instrument parameters so that they are out of their range, for example the high voltage of the photomultiplier tube or the pressure of the gaseous nitrogen. If more than one detector is read out per simulated range error, the requirement is not met.

10.7 Storage of data

10.7.1 Requirements

a) Instrument parameters: It shall not be possible for the user to modify the instrument parameters (for example calibration coefficients, range for the high voltage of a photomultiplier tube). Exception: Modification of instrument parameters shall be possible only via the paths provided by the software (for example calibration measurement or input by authorized user via a password whose default value is defined in the instruction manual and can be changed by the user). A history of the values and changes of all parameters shall be available for the user.

NOTE 1 One possible technical solution is:

All data are combined in well-defined data sets. The whole data set is protected by a digital signature. The software reads the data set, calculates the digital signature and compares it with its nominal value contained in the data set. In case any change in a data set is detected, the data set is marked as invalid by the program and not used any more.

b) Measurement results: All measurement results including all relevant information necessary to trace back to and reconstruct the measurement that generated the stored result (authenticity) shall be recorded or stored without any change automatically after each measurement. This contains at least date and time of the readout, the identification of the dosemeter (for example number) and of the reader, the indicated value and the calibration coefficients used. Such documentation may be made either by hardcopy printout or in electronic form on hard disks in connection with software for data display: viewing program which is a “data-relevant program”, see Note to 10.2.1. This software shall not use (for example, display or print) changed data. In addition, the long-term storage shall have a capacity which is sufficient for the intended purpose. The data shall be protected against loss.

NOTE 2 One possible technical solution is:

All data specific for a certain measurement are combined in well-defined data sets and stored in binary format automatically after the measurement. The whole data set is protected by a digital signature. This data set does not have to contain the instrument parameters, only the information where the actual instrument parameters are available, for example file name, location, and date and time of the file. The viewing program reads the stored data and checks its digital signature. In case any change in a data set is detected, the data set is marked as invalid by the program and not used any more. The data are stored on two hard drives supervised by a raid-controller. The software activates the write protection of the operating system.

10.7.2 Method of test

Documentation: The way of storing the data and the measures to prevent any change or loss of these data, for example the procedure to evaluate a checksum, shall apparently be effective (for example, it shall cover the entire data set and a formula to calculate the remaining storage capacity shall be applied). All information to trace back to and reconstruct the measurement shall be contained. If a digital signature is used, the software to read and display the data (viewing program) shall check it.

Practical tests:

a) Make sure that all relevant data necessary to reconstruct the measurement are stored in a data file directly after a measurement and that there is no button or menu item to interrupt or disable the automatic storing.

b) Try to modify instrument parameters or indicated values via the software itself. If this is possible without specific knowledge, for example a password or details of the software structure, the requirement is not met.

c) Open a data file with the aid of an editor and modify single bits, then close the file. If the software of the dosimetry system still reads the data file and delivers the modified value, then the requirement is not met.

d) Try to delete a data file from the hard disc using the standard command of the operating system. If this is possible without a warning or without specific knowledge, for example a password or details of the software structure, the requirement is not met.

e) Check that a warning is given and the measurement stops in case the storage is full or removed.

f) In case data are printed out and stored, make sure that both are identical.

For long term storage of data, it is necessary to consider the limited time (for example a few years) special data formats can be read (for example a CD or DVD).

10.8 Transmission of data

10.8.1 Requirements

In case data are transmitted from one device to another (for example from a reader to a PC), these data shall contain all necessary information to further process them correctly. It shall not be possible to modify, delete or add something to these data. In addition, the receiving part of the dosimetry system, for example the computer, shall make sure that the received data are authentic. That means it shall be recognized if the data come from a device other than the reader or dosemeter assigned to the dosimetry system. In case the connection between the transmitting parts is unavailable or delays the transmission, at most one indicated value shall get lost. In case a data set is transmitted incorrectly (in spite of the transmission protocol tried to repeat the transmission until it succeeded) the data set shall not be used.

NOTE One possible technical solution is:

All transmitted data are combined in well-defined data sets including date and time of the generation of the data set, a running number, an identification of the transmitting part, for example serial number of the reader, and the relevant data. The whole data set is protected by a digital signature. The reader encrypts the data transmitted to the software with a key known to the type tested software only (for example its hash code) via a handshake sequence. The receiving part, for example computer, checks the data by making sure that no running number is missing (or double) and that the identification of the transmitting part is the correct one. In case a transmitted data set is incorrect, it is marked as invalid by the program and not used any more.

10.8.2 Method of test

Documentation: All information to trace back to the measurement and for further processing the measurement data shall be contained in the data set. If a digital signature is used, the software to receive the data shall check it. Secret data (for example key initial value if used) shall be kept secret against spying out with simple tools (hacking). Check that data are digitally signed to ensure their proper identification and authentication.

Practical tests: Spot checks shall show that no relevant data get lost due to a transmission interruption (for example, unplug a cable or put a wireless local area network (WLAN) out of range).

10.9 Hardware interfaces and software interfaces

10.9.1 Requirements

All entered commands or values received via interfaces (for example, user interfaces such as keyboard, software interfaces, barcode scanner, RFID reader, and over the air updates) shall influence the instruments data and functions in an admissible way only. All commands or values have to be defined, i.e. they shall either have a meaning and processing by the instrument shall be possible, or the instrument shall identify them as being invalid. Invalid commands shall not have any effect whatsoever on the data and functions of the instrument.

NOTE 1 In principle it is possible to circumvent a software interface. This can usually be excluded by software separation, see Note to 10.2.1, when the data-relevant part of the software is realized in a separate binary file.

NOTE 2 One possible technical solution is:

User interfaces: A module in the data-relevant software filters out inadmissible commands. Only this module receives commands, and there is no circumvention of it. Any false input is blocked. The user is controlled or guided when inputting commands by a special software module. This guiding module is inextricably linked with the module that filters out the inadmissible commands.

Software interfaces: There is a software module that receives and interprets commands from the interface. This module belongs to the data-relevant software. It only forwards allowed commands to the other data-relevant software modules. All unknown or not allowed commands are rejected and have no impact on the data-relevant software or measurement data.

10.9.2 Method of test

Documentation: The list of commands and parameters that are accepted by the hardware interfaces and software interfaces shall apparently be complete. For example if on the basis of this list and the information concerning the structure of the software it is not possible to perform a calibration, the list cannot be complete.

Practical test: Using the supplied software and the peripheral equipment, carry out practical tests (spot checks) with both documented and undocumented commands and test all menu items if any. If there is any accessory software accompanying the dosimetry system for operating the interface via an additional computer, for some of the commands that are available it shall be checked that the dosimetry system works as documented. In addition, some other commands shall be given. In case the dosimetry system is affected by this, the requirement is not met.

10.10 Documentation for the software test

10.10.1 Requirements

a) Documentation in the instruction manual: All dosimetric relevant parts, menus and submenus of the software including the viewing program to read and display stored data shall be described in the instruction manual, see Clause 9.

b) Documentation for the type test: In addition to the documentation in the manual, the following information shall be given by the manufacturer for the purpose of type testing:

- a description of the structure of the software including the data-relevant software functions and the meaning of data; in case of software separation a description of the software interface; the measures to protect the software; see 10.2;
- the method to evaluate the identification; see;10.3;
- the measures to prevent any change of the software and of the presented data and how their authenticity is guaranteed; see 10.4;
- the measures to recognize faulty operation; see 10.5;
- a list of all parameters, their ranges and nominal values, the method to make sure that they are in allowed ranges, where they are stored and how they may be viewed, including their history; see 10.6;
- the way of storing the data automatically; a description of all fields of a data set; the method used for ensuring their authenticity; the management of exceptional cases when storing data (for example full storage); the method of the viewing program to detect corruptions; the measures to prevent any change or loss of the stored data; see 10.7;
- the way of transmitting the data; a description of all fields of a data set; the method used for ensuring their authenticity; the management of exceptional cases when transmitting data (for example cable disconnected); the measures to prevent any change, loss of or addition to transmitted data; see 10.8;
- a description of the software interface, especially which data domains realize the interface; a complete list of commands and parameters that are accepted by the hardware interfaces and software interfaces, including a declaration of completeness of this list and a brief description of each command; see 10.9;
- the necessary characteristics of the operating system and of the hardware of the computer;
- an overview of the security aspects of the operating system, for example, protection, user accounts, or privileges.

This information can be confidential and only be used by the testing laboratory for the purpose of type testing.

10.10.2 Method of test

Documentation: Check that all documentation required in 10.10.1 is completely given and fulfils its purpose.

Practical tests: By using the software during the type test a lot of menus will be used. All of them shall be documented in the instruction manual. The rest of the menus shall be checked by “playing” with the running software and comparing the corresponding parts of the instruction manual. If not all of the menus found in the software and in the instruction manual fit together, the requirement is not met.

11 Radiation performance requirements and tests (dosimetry system)

11.1 General

All influence quantities dealt with in this clause are of type F, see 3.16.

If the dosimetry system uses more than one signal for the evaluation of the indicated value, Clause 12 shall be taken into account. The necessary information for the test according to Clause 12 shall be gained during the tests according to this Clause 11.

If the dosimetry system is intended to measure both photon and beta radiation and if it uses for both types of radiation the same signal for the evaluation of the indicated value, then the same reference radiation quality has to be chosen for both types of radiation.

This meets practice: If only one signal (and thus one detector) is used, only one calibration coefficient can be applied which is the same for both photon and beta radiation. Thus, the reference radiation quality shall be the same for the dependence on the particle energy, the angle of incidence and the type of radiation.

11.2 Coefficient of variation

The statistical fluctuations of the indicated value shall fulfil the requirements given in line 6 of Table 8 to Table 13.

The test shall be performed together with the test regarding non-linearity. Therefore, the method of test is described in the following 11.3.

11.3 Non-linearity

11.3.1 Requirements

The variation of the response due to a change of the dose equivalent shall not exceed the values given in line 7 of Table 8 to Table 13 over the entire measuring range for photon and/or beta reference radiation.

11.3.2 Method of test

a) Source to be used

The tests shall be performed with radiation from ^{137}Cs or ^{60}Co sources or other radiation qualities specified in the ISO 4037 series. In case the dosemeter has separate detectors for photon and beta radiation, the test shall be performed with a beta source as well, for example ^{90}Sr/^{90}Y. In case the detector signal strongly depends on the particle energy, i.e. $\max(r_{E,\alpha})/\min(r_{E,\alpha}) > 2$, the test shall also be performed using different radiation qualities, e.g. in addition with low energy photon radiation qualities. During the tests, the dosemeter shall be irradiated on the required phantom (see 5.1.5) from the reference direction.

NOTE 1 The irradiations can be done free in air if the correction factor for irradiating free in air instead of on the phantom is applied. This correction factor is specific for the dosemeter under test and the radiation quality used and is therefore determined specifically. Irradiations free in air may be performed at smaller distances resulting in smaller field diameters as the omitted phantom does not have to be illuminated.

b) Tests to be performed

The tests shall be performed separately with photon radiation or beta radiation (the type of radiation for which the dosimetry system is specified).

The response shall be measured for at least the following dose values: at each limit of each order of magnitude of the measuring range, at approximately 30 % of each full order of magnitude, at the limits of the measuring range and, in addition, in the vicinity of range changes (if known). In total, n repeated measurements at each of the w dose values shall be performed.

NOTE 2 If, for example, the measuring range is from 0.1 mSv up to 2 Sv, the corresponding dose values are 0,1 and 0,3 mSv; 1 and 3 mSv; 10 and 30 mSv; 100 and 300 mSv; 1 Sv and 2 Sv.

For every dose C_i, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

11.3.3 Interpretation of results

If, using the w values of the coefficient of variation and the values of c_1 and c_2 given in Table 2, shows that

- for w – 2 dose values the coefficient of variation is less than c_1 times the limits given in line 6 of Table 8 to Table 13 and
- for the remaining two dose (rate) values – which shall not be adjacent – the coefficients of variation are less than c_2 times the limits given in line 6 of Table 8 to Table 13,

then the requirement of 11.2 is considered to be met.

NOTE 1 This method of test is explained in detail in Brunzendorf and Behrens (2007), see bibliography. It takes into account the fact that it is not possible to measure the coefficient of variation precisely with a reasonable effort. Therefore, the test incorporates the statistical method of a one-sided chi-square-test. A dosimetry system with a coefficient of variation being equivalent to 0,9-times the required limit passes the test with a probability of about 80 %. A dosimetry system with a coefficient of variation being equivalent to 1,1-times the required limit fails the test with a probability of about 80 %.

NOTE 2 If the interpretation of the results was that "for every dose C_i, the value $s_i / \overline{G}_i$ would not be larger than the required limit given in line 6 of Table 8 to Table 13 (method of test so far), then a dosimetry system with a coefficient of variation being equivalent to 0,9-times the required limit would fail the test with a probability of about 98 %. It can also be explained as: If the method of test "$s_i / \overline{G}_i$ is larger than the required value" is fulfilled with a probability of about 85 %, then the true coefficient of variation will not be larger than 0,63-times the required limit.

If, in addition, for each of the resulting groups (dose values C_i), the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G}_i}{\overline{G}_{\text{r},0}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r},0}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.3.1 is considered to be met.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r},0}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel};\,\text{r},0} + U^2_{C,\text{rel};\,i}}$ with the relative expanded uncertainties $U_{C,\text{rel};\,\text{r},0}$ and $U_{C,\text{rel};\,i}$ of the conventional quantity values $C_{\text{r},0}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\text{rel};\,\text{r},0}$ and $U_{C,\text{rel};\,i}$ are correlated, this shall be taken into account. For $U_{C,\text{rel}}$, see 5.2.2.

Table 2 – Values of c_1 and c_2 for w different dose values and n indications for each dose value

w	Value of c_1 for n equal							Value of c_2 for n equal						
	4	7	10	15	20	25	∞	4	7	10	15	20	25	∞
5	1,000	1,007	1,009	1,009	1,009	1,009	1	1,499	1,400	1,344	1,290	1,255	1,231	1
6	1,058	1,051	1,046	1,039	1,035	1,032	1	1,572	1,454	1,389	1,326	1,287	1,261	1
8	1,147	1,117	1,100	1,084	1,074	1,067	1	1,687	1,536	1,458	1,383	1,336	1,304	1
10	1,215	1,166	1,141	1,117	1,102	1,092	1	1,772	1,597	1,508	1,423	1,372	1,335	1
12	1,269	1,205	1,173	1,143	1,124	1,112	1	1,840	1,645	1,548	1,455	1,399	1,360	1
14	1,315	1,238	1,200	1,164	1,142	1,128	1	1,895	1,684	1,578	1,480	1,421	1,379	1
16	1,351	1,265	1,222	1,182	1,158	1,142	1	1,940	1,716	1,605	1,502	1,440	1,396	1
18	1,388	1,289	1,242	1,211	1,171	1,153	1	1,980	1,743	1,628	1,409	1,453	1,409	1
20	1,418	1,311	1,259	1,233	1,183	1,164	1	2,015	1,767	1,646	1,394	1,466	1,421	1
25	1,483	1,355	1,295	1,240	1,210	1,186	1	2,081	1,812	1,683	1,563	1,445	1,444	1
50	1,683	1,494	1,407	1,328	1,283	1,252	1	2,275	1,945	1,789	1,646	1,561	1,504	1

11.4 Overload characteristics, after-effects, and reusability

11.4.1 Requirements

The requirements are subdivided into three parts:

a) Recognition of overload

When the dosemeter is irradiated with a high dose as given in line 8 of Table 8 to Table 13, the system shall display an indicated dose larger than the upper dose limit of the range of measurement, H_{up}, or an overload message.

b) After-effects

If a dosemeter irradiated to high dose values produces after-effects on any subsequent measurement, suitable measures shall be taken to ensure that the requirements of this document are met in the subsequent measurements.

c) Reusability

If the dosemeters cannot be reused indefinitely or if usability depends on the history of the dosemeter, this fact is stated by the manufacturer, see 7.5. Often, a high dose during the last irradiation negatively affects the reusability.

11.4.2 Method of test

For this test, four groups of dosemeters shall be exposed to a reference source. The tests shall be performed with radiation from ^{137}Cs or ^{60}Co sources or other radiation qualities specified in the ISO 4037 series.

Group 1: reference group: n (≥ 5) dosemeters shall be irradiated with $C_{\mathrm{r},0}$, see Table 7.

Group 2: at least one dosemeter shall be irradiated with a high dose equivalent as given in line 8 of Table 8 to Table 13.

Group 3: n (≥ 10) dosemeters shall be irradiated with a dose equivalent equal to the lower limit of the measuring range, H_{low}.

Group 4: n (≥ 10) dosemeters shall be irradiated with the dose up to which they are reusable. This dose is given by the manufacturer, see 7.5. Then, the usual method to prepare the dosemeters for a new irradiation shall be applied. Finally, the dosemeters shall be irradiated with a dose equivalent equal to the lower limit of the measuring range, H_{low}.

The dosemeters shall be read out in that order.

For every dose value, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

11.4.3 Interpretation of the results

The indicated value of the second group (only one dosemeter) shall be at least the upper limit of the measuring range, H_{up}, or an overload message shall be displayed on the system.

If for the three other groups of dosemeters, the inequality $r_{\mathrm{min}} - U_{C,\mathrm{com}} \leq \left(\frac{\overline{G_i}}{\overline{G_{\mathrm{r},0}}} \pm U_{\mathrm{com}} \right) \cdot \frac{C_{\mathrm{r},0}}{C_i} \leq r_{\mathrm{max}} + U_{C,\mathrm{com}}$ with r_{min} and r_{max} taken from line 7 of Table 8 to Table 13 is valid and for groups 3 and 4 the value $\frac{s_i}{\overline{G_i}}$ is smaller than the figures given in line 6 of Table 8 to Table 13, then the requirements of 11.4.1 are considered to be met.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\mathrm{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\mathrm{r},0}}{C_i}$: $U_{C,\mathrm{com}} = \sqrt{U^2_{C,\mathrm{rel};\mathrm{r},0} + U^2_{C,\mathrm{rel};i}}$ with the relative expanded uncertainties $U_{C,\mathrm{rel};\,\mathrm{r},0}$ and $U_{C,\mathrm{rel};\,i}$ of the conventional quantity values $C_{\mathrm{r},0}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\mathrm{rel};\,\mathrm{r},0}$ and $U_{C,\mathrm{rel};\,i}$ are correlated, this shall be taken into account. For $U_{C,\mathrm{rel}}$, see 5.2.2.

11.5 Radiation energy and angle of incidence for $H_p(10)$ or $H^*(10)$ dosemeters

11.5.1 Photon radiation

11.5.1.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges shall not exceed the values given in line 9 of Table 8 and Table 11 for $H_p(10)$ and $H^*(10)$, respectively.

11.5.1.2 Method of test

The following radiation qualities specified in the ISO 4037 series shall be used:

N-15, N-20, N-30, N-40, N-60, N-80, N-100, N-150, N-200, N-300,
S-Cs (^{137}Cs), S-Co (^{60}Co), R-C (4,4 MeV), R-F (6,7 MeV).

Irradiations shall be performed for the energies and angles of incidence α given in Table 3:

Table 3 – Angles of incidence of irradiation for $H_p(10)$ and $H^*(10)$ dosemeters

α	$H_p(10)$ dosemeters (irradiations on phantom, see 5.1.5)	$H^*(10)$ dosemeters (irradiations free in air)
0°	For all radiation qualities whose mean energy falls within the rated range of energy	For all radiation qualities whose mean energy falls within the rated range of energy
± 60°	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
± 75°	In case 75° ≤ α_{max}: Three lowest energies in rated range of energy, otherwise not mandatory	For workplace dosemeters with 75° ≤ α_{max} and for environmental dosemeters three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	For environmental dosemeters three lowest energies in rated range of energy
90°	This test is given in 11.8	For environmental dosemeters three lowest energies in rated range of energy
± (180°– α_{max})	No test	As for α_{max}, not necessary if the dosemeter is symmetrical
± 105°	No test	As for 75°, not necessary if the dosemeter is symmetrical
± 120°	No test	As for 60°, not necessary if the dosemeter is symmetrical
180°	No test	As for 0° angle of incidence, not necessary if the dosemeter is symmetrical

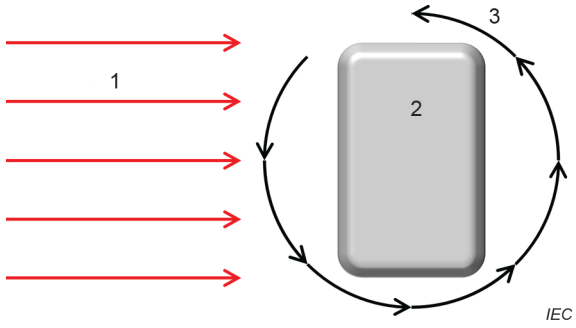
NOTE 1 The dosemeter is symmetrical, if all parts including filters are symmetrical with respect to a plane through the centre of the detector and perpendicular to the reference direction.

NOTE 2 For personal dose quantities: Also take into account 8.4 e) and line 11 of Table 8.

For $\alpha \neq 0°$ and for $\alpha \neq 180°$ the tests shall be performed in two perpendicular planes parallel to the reference direction and going through the reference point of the dosemeter. Different directions for one angle of incidence (for example + 60° and – 60°) shall only be irradiated if the construction of the dosemeter is not symmetrical with respect to a change of that direction.

For $H^*(10)$ dosemeters and $\alpha = 90°$, i.e. the reference direction is orientated perpendicular to the radiation beam, the dosemeter shall be rotated during the irradiation about its reference direction as rotation axis. If no rotation during the irradiation is possible, eight subsequent

irradiations with different polar angles in steps of 45° can be used irradiating the same dosemeter, see Figure 1 for illustration.



Key

1 Radiation field

2 Dosemeter badge, front face

3 Stepwise rotation in steps of 45° around the reference orientation (perpendicular to the drawing plane)

Figure 1 – Stepwise irradiation of an $H^*(10)$ dosemeter at 90° angle of incidence

For non-symmetrical $H_p(10)$ dosemeters (see Note 1 and 8.4 e)), the dosemeter shall in addition to the normal test be placed on the front side of the phantom with its back to the radiation source (checking whether wearing in the wrong direction gives bad results).

For every radiation quality, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

NOTE 3 i refers to a group of dosemeters irradiated equally, for example N-30, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 4 For an $H_p(10)$ dosemeter, for each of the three lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

NOTE 5 For an $H^*(10)$ dosemeter, for each of the three lowest radiation energies, at least ten groups of dosemeters are irradiated: one at 0°, four at 60°, four at 75° and one at 90°.

11.5.1.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G}_i}{\overline{G}_{\text{r},0}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r},0}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.5.1.1 is considered to be met. The values for r_{min} and r_{max} are given in line 9 of Table 8 and Table 11.

Exception: In case the expression $\left(\frac{\overline{G}_i}{\overline{G}_{\text{r},0}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r},0}}{C_i}$ for 0° angle of incidence differs by only 0,05 or less from the allowed limit and no angular irradiations have been performed at this energy, the corresponding angular irradiations have to be performed for those specific energies.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r},0}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel};\text{r},0} + U^2_{C,\text{rel};i}}$ with the relative expanded uncertainties $U_{C,\text{rel};\text{r},0}$ and $U_{C,\text{rel};i}$ of the conventional quantity values $C_{\text{r},0}$ and C_i for the

different radiation qualities, respectively. In case $U_{C,\mathrm{rel};\,\mathrm{r},0}$ and $U_{C,\mathrm{rel};\,i}$ are correlated, this shall be taken into account. For $U_{C,\mathrm{rel}}$, see 5.2.2.

11.5.2 Beta radiation

11.5.2.1 Requirements

As the dosemeter is intended to measure $H_\mathrm{p}(10)$ or $H^*(10)$, the indicated value due to beta radiation with energies up the energy equivalent of ^{90}Sr/^{90}Y shall be less than $0{,}1 \cdot H_\mathrm{p}(0{,}07)$ (see line 10 of Table 8 and Table 11).

NOTE For beta radiation, $H_\mathrm{p}(10)$ and $H^*(10)$ are not suitable quantities to estimate the effective dose equivalent.

11.5.2.2 Method of test

For this test, n (≥ 4) dosemeters shall be exposed at 0° angle of incidence to beta reference radiation specified in ISO 6980:

– ^{90}Sr/^{90}Y (mean energy ≈ 0,8 MeV).

The dose equivalent shall be at least $H_\mathrm{p}(0{,}07)$ = 10 mSv = C.

NOTE Details of the reference radiation and the calibration procedure are given in ISO 6980.

For this radiation quality, the mean indicated value $\overline{G}$ and the standard deviation s shall be determined.

11.5.2.3 Interpretation of the results

If $\overline{G} + U_\mathrm{m} \leq 0{,}1 \cdot C$ is valid, then requirement of 11.5.2.1 is considered to be met.

U_m is calculated according to formula (A.3).

11.6 Radiation energy and angle of incidence for $H_\mathrm{p}(3)$ or $H'(3)$ dosemeters

11.6.1 Photon radiation

11.6.1.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges shall not exceed the values given in line 9 of Table 9 and Table 12 for $H_\mathrm{p}(3)$ and $H'(3)$, respectively.

11.6.1.2 Method of test

The following radiation qualities specified in ISO 4037 shall be used:

N-10, N-15, N-20, N-30, N-40, N-60, N-80, N-100, N-150, N-200, N-300, S-Cs (^{137}Cs), S-Co (^{60}Co), R-C (4,4 MeV), R-F (6,7 MeV).

Irradiations shall be performed for the energies and angles of incidence α given in Table 4:

Table 4 – Angles of incidence of irradiation for $H_p(3)$ and $H'(3)$ dosemeters

α	$H_p(3)$ dosemeters (irradiations on phantom, see 5.1.5)	$H'(3)$ dosemeters (irradiations free in air)
0°	For all radiation qualities whose mean energy falls within the rated range of energy	For all radiation qualities whose mean energy falls within the rated range of energy
± 60°	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
± 75°	In case 75° ≤ α_{max}: Three lowest energies in rated range of energy, otherwise not mandatory	For environmental dosemeters three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	For environmental dosemeters three lowest energies in rated range of energy
90°	This test is given in 11.8	For environmental dosemeters three lowest energies in rated range of energy
± (180°– α_{max})	No test	For environmental dosemeters three lowest energies in rated range of energy
± 105°	No test	For environmental dosemeters three lowest energies in rated range of energy
± 120°	No test	Three lowest energies in rated range of energy
180°	No test	Three lowest energies in rated range of energy

NOTE 1 Also take into account 8.4 e) and line 11 of Table 9.

For $\alpha \neq 0°$ and for $\alpha \neq 180°$, the tests shall be performed in two perpendicular planes parallel to the reference direction and going through the reference point of the dosemeter. Different directions for one angle of incidence (for example + 60° and – 60°) shall only be irradiated, if the construction of the dosemeter is not symmetrical with respect to a change of that direction.

For non-symmetrical $H_p(3)$ dosemeters (see Note 1 and 8.4 e)), the dosemeter shall in addition to the normal test be placed on the front side of the phantom with its back to the radiation source (checking whether wearing in the wrong direction gives incorrect results).

For every radiation quality, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example N-30, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For an $H_p(3)$ dosemeter, for each of the three lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

11.6.1.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{min} - U_{C,com} \leq \left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{com} \right) \cdot \frac{C_{r,0}}{C_i} \leq r_{max} + U_{C,com}$ is valid, then the requirement of 11.6.1.1 is considered to be met. The values for r_{min} and r_{max} are given in line 9 of Table 9.

Exception: In case the expression $\left(\frac{\overline{G}_i}{\overline{G}_{r,0}} \pm U_{com} \right) \cdot \frac{C_{r,0}}{C_i}$ for 0° angle of incidence differs by only 0,05 or less from the allowed limit and no angular irradiations have been performed at this energy, the corresponding angular irradiations have to be performed for those specific energies.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,com}$ is the combined relative expanded uncertainty of $\frac{C_{r,0}}{C_i}$: $U_{C,com} = \sqrt{U^2_{C,rel;r,0} + U^2_{C,rel;i}}$ with the relative expanded uncertainties $U_{C,rel;r,0}$ and $U_{C,rel;i}$ of the conventional quantity values $C_{r,0}$ and C_i for the different radiation qualities, respectively. In case $U_{C,rel;r,0}$ and $U_{C,rel;i}$ are correlated, this shall be taken into account. For $U_{C,rel}$, see 5.2.2.

11.6.2 Beta radiation

11.6.2.1 Requirements

Requirement A: The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges for beta radiation shall not exceed the values given in line 10 of Table 9 and Table 12.

Requirement B: As the dosemeter is intended to measure $H_p(3)$ or $H'(3)$, the indicated value due to beta radiation with energies up the energy equivalent of ^{85}Kr shall be less than $0{,}1 \cdot H_p(0{,}07)$ (see line 10 of Table 9 and Table 12).

11.6.2.2 Method of test

For requirement A:

The following reference radiation qualities specified in ISO 6980 shall be used:

^{90}Sr/^{90}Y (mean energy ≈ 0,8 MeV); ^{106}Ru/^{106}Rh (mean energy ≈ 1,2 MeV).

As long as no conversion coefficients for the conversion from personal absorbed dose in 0,07 mm depth, $D_p(0{,}07)$, to $H_p(3)$ and $H'(3)$ are available in ISO 6980-3, the values given in Annex E shall be used.

The tests shall be performed for those radiation qualities whose mean energy falls in the rated range of energy. Angles of incidence shall be: $\alpha = 0°$, $\alpha = \pm 45°$, $\alpha = \pm 60°$ and $\alpha = \pm 75°$ if included in the rated range of angle of incidence in two perpendicular planes containing the reference direction through the reference point of the dosemeter.

For every radiation quality, the mean indicated value $\overline{G}_{i,A}$ and the standard deviation $s_{i,A}$ shall be determined.

NOTE 1 Details of the reference radiation and the calibration procedure are given in ISO 6980.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example Sr-90, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For $H_p(3)$ and $H'(3)$ dosemeters, at each of the two lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

For requirement B:

For this test, n (≥ 4) dosemeters shall be exposed at 0° angle of incidence to beta reference radiation specified in ISO 6980:

– ^{85}Kr (mean energy ≈ 0,24 MeV).

The dose equivalent shall be at least $H_p(0{,}07)$ = 10 mSv = C.

For this radiation quality, the mean indicated value $\overline{G}_B$ and the standard deviation s_B shall be determined.

11.6.2.3 Interpretation of the results

For requirement A:

If, for every radiation quality, the inequality $r_{min} - U_{C,com} \leq \left(\frac{\overline{G}_{i,A}}{\overline{G}_{r,0,A}} \pm U_{com} \right) \cdot \frac{C_{r,0,A}}{C_{i,A}} \leq r_{max} + U_{C,com}$ is valid, then requirement A of 11.6.2.1 is considered to be met. The values for r_{min} and r_{max} are given in line 10 of Table 9.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,com}$ is the combined relative expanded uncertainty of $\frac{C_{r,0}}{C_i}$: $U_{C,com} = \sqrt{U^2_{C,rel;r,0} + U^2_{C,rel;i}}$ with the relative expanded uncertainties $U_{C,rel;r,0}$ and $U_{C,rel;i}$ of the conventional quantity values $C_{r,0}$ and C_i for the different radiation qualities, respectively. In case $U_{C,rel;r,0}$ and $U_{C,rel;i}$ are correlated, this shall be taken into account. For $U_{C,rel}$, see 5.2.2.

For requirement B:

If $\overline{G}_B + U_m \leq 0{,}1 \cdot C$ is valid, then requirement B of 11.6.2.1 is considered to be met.

U_m is calculated according to formula (A.3).

11.7 Radiation energy and angle of incidence for $H_p(0{,}07)$ or $H'(0{,}07)$ dosemeters

11.7.1 Photon radiation

11.7.1.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges shall not exceed the values given in line 9 of Table 10 and Table 13 for $H_p(0{,}07)$ and $H'(0{,}07)$, respectively.

11.7.1.2 Method of test

The following radiation qualities specified in ISO 4037 shall be used:

N-10, N-15, N-20, N-30, N-40, N-60, N-80, N-100, N-150, N-200, N-300, S-Cs (^{137}Cs), S-Co (^{60}Co), R-C (4,4 MeV), R-F (6,7 MeV).

Irradiations shall be performed for the energies and angles of incidence α given in Table 5:

Table 5 – Angles of incidence of irradiation for $H_p(0,07)$ and $H'(0,07)$ dosemeters

α	$H_p(0,07)$ dosemeters (irradiations on phantom, see 5.1.5)	$H'(0,07)$ dosemeters (irradiations free in air)
0°	For all radiation qualities whose mean energy falls within the rated range of energy	For all radiation qualities whose mean energy falls within the rated range of energy
± 60°	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
± 75°	In case 75° ≤ α_{max}: Three lowest energies in rated range of energy, otherwise not mandatory	For environmental dosemeters three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	For environmental dosemeters three lowest energies in rated range of energy
90°	This test is given in 11.8	For environmental dosemeters three lowest energies in rated range of energy
± (180° − α_{max})	No test	For environmental dosemeters three lowest energies in rated range of energy
± 105°	No test	For environmental dosemeters three lowest energies in rated range of energy
± 120°	No test	Three lowest energies in rated range of energy
180°	No test	Three lowest energies in rated range of energy

NOTE 1 For personal dose quantities: Also take into account 8.4 e) and line 11 of Table 10.

For $\alpha \neq 0°$ and for $\alpha \neq 180°$, the tests shall be performed in two perpendicular planes parallel to the reference direction and going through the reference point of the dosemeter. Different directions for one angle of incidence (for example + 60° and – 60°) shall only be irradiated, if the construction of the dosemeter is not symmetrical with respect to a change of that direction.

For $H'(0,07)$ dosemeters and $\alpha = 90°$, the dosemeter shall be rotated about its reference direction during the irradiation. If no rotation is possible, eight subsequent irradiations with different polar angles in steps of 45° can be done irradiating the same dosemeter. As α is 90°, the reference direction is orientated perpendicular to the radiation beam. The rotation may be omitted if the dosemeter has a holder defining the orientation with respect to the expected direction of radiation incidence.

For non-symmetrical $H_p(0,07)$ dosemeters (see Note 1 and 8.4 e)), the dosemeter shall in addition to the normal test be placed on the front side of the phantom with its back to the radiation source (checking whether wearing in the wrong direction gives incorrect results).

For every radiation quality, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example N-30, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For an $H_p(0,07)$ dosemeter, for each of the three lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

NOTE 4 For an $H'(0,07)$ dosemeter, for each of the three lowest radiation energies, at least ten groups of dosemeters are irradiated: one at 0°, four at 60°, four at 75° and one at 90°.

11.7.1.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.7.1.1 is considered to be met. The values for r_{min} and r_{max} are given in line 9 of Table 10 and Table 13.

Exception: In case the expression $\left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i}$ for 0° angle of incidence differs by only 0,05 or less from the allowed limit and no angular irradiations have been performed at this energy, the corresponding angular irradiations have to be performed for those specific energies.

U_{com} is calculated according to formula (A.5), Example 2. $U_{\text{C,com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel;r,0}} + U^2_{C,\text{rel;}i}}$ with the relative expanded uncertainties $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ of the conventional quantity values $C_{\text{r,0}}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel; }i}$ are correlated, this shall be taken into account. For $U_{C,\text{rel}}$, see 5.2.2.

11.7.2 Beta radiation

11.7.2.1 Requirements

The variation of the relative response due to a change of the radiation energy and angle of incidence within the rated ranges for beta radiation shall not exceed the values given in line 10 of Table 10 and Table 13.

In case these requirements are not met, the requirements given in 11.9 shall be met.

NOTE Subclause 11.7.2 deals with the measurement of beta dose. Subclause 11.9 deals with the indication of the presence of beta dose.

11.7.2.2 Method of test

The following reference radiation qualities specified in ISO 6980 shall be used:

^{147}Pm (mean energy ≈ 0,06 MeV); ^{204}Tl or ^{85}Kr (mean energy ≈ 0,24 MeV);

^{90}Sr/^{90}Y (mean energy ≈ 0,8 MeV); ^{106}Ru/^{106}Rh (mean energy ≈ 1,2 MeV).

As long as no conversion coefficients for the conversion from personal absorbed dose in 0,07 mm depth, $D_{\text{p}}(0,07)$, to the personal dose equivalent, $H_{\text{p}}(0,07)$, are available in ISO 6980-3 for ^{106}Ru/^{106}Rh, the values given in Annex E shall be used.

The tests shall be performed for those radiation qualities whose mean energy falls in the rated range of energy. Angles of incidence shall be: $\alpha = 0°$, $\alpha = \pm 45°$, as well as $\alpha = \pm 60°$ and $\alpha = \pm 75°$ if included in the rated range of angle of incidence in two perpendicular planes containing the reference direction through the reference point of the dosemeter.

For every radiation quality, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

NOTE 1 Details of the reference radiation and the calibration procedure are given in ISO 6980.

NOTE 2 i refers to a group of dosemeters irradiated equally, for example Kr-85, 60° (from above). That means, the different directions (horizontal from the right and left; vertical from above and the bottom) for one angle of incidence are not averaged.

NOTE 3 For an $H_p(0,07)$ dosemeter, at the lowest or at each of the two lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

11.7.2.3 Interpretation of the results

If, for every radiation quality, the inequality $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ is valid, then the requirement of 11.7.2.1 is considered to be met. The values for r_{min} and r_{max} are given in line 10 of Table 10 and Table 13.

U_{com} is calculated according to formula (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel;r,0}} + U^2_{C,\text{rel;}i}}$ with the relative expanded uncertainties $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel;}i}$ of the conventional quantity values $C_{\text{r,0}}$ and C_i for the different radiation qualities, respectively. In case $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel;}i}$ are correlated, this shall be taken into account. For $U_{C,\text{rel}}$, see 5.2.2.

11.8 Over indication due to radiation incident from the side of an $H_p(10)$, $H_p(3)$ or $H_p(0,07)$ dosemeter

11.8.1 Requirements

If the dosemeter is irradiated free in air from the side (α_{max} to 180°–α_{max}), the indicated value shall not exceed 2 times the indicated value resulting from an irradiation free in air with the same radiation quality from the front (0°). This shall apply to all radiation energies within the rated range of energy.

NOTE 1 This requirement prevents the acceptance of a detector with a high atomic number material without sufficient shielding which may cause a large over response from the side.

NOTE 2 If α_{max} = 60°, this means an irradiation from 60° to 120°.

NOTE 3 No lower limit is required as the conventional quantity value is zero for beta radiation and for low energy photon radiation.

11.8.2 Method of test

For several radiation energies, the test can be performed by examining the materials in front of the detector(s) and the surrounding material. If it can be anticipated due to physical absorption coefficients that the material at the side results in more absorption than in the front, the tests can be omitted for these radiation energies.

For the remaining radiation energies, irradiations shall be performed for those polar angles β (regions of the side of the badge) at which the surrounding material does not seem to be thick enough. At these “weak points”, at least two groups of dosemeters shall be irradiated free in air to an ambient dose equivalent of $H^*(10) \approx 3$ mSv:

Group 1: The dosemeters shall be irradiated at an angle of incidence of 0°.

Further groups: Irradiations shall be performed at the angle of incidences β corresponding to the “weak points”. The azimuthal angle of incidence shall be varied during the irradiation between α_{max} and 180°–α_{max} in steps of 15° including 90° resulting in the indicated value $\overline{G}_{\alpha_{\text{max}} \text{ to } 180° - \alpha_{\text{max}}}$.

Separate groups shall be irradiated separately for every polar angle β (i.e. for every “weak point”).

NOTE In case of α_{max} = 60°, the irradiation of each badge is performed in three equivalent fractions at 75°, 90°, and 105°.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

11.8.3 Interpretation of the results

If, for every polar angle examined in accordance with 11.8.2, the inequality $\frac{\overline{G}_{\alpha_{max}\,\text{to}\,180°-\alpha_{max}}}{\overline{G}_{0°}} + U_{com} \leq 2$ is valid, then the requirement of 11.8.1 is considered to be met.

U_{com} is calculated according to formula (A.5), Example 2. This calculation presumes that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

11.9 Indication of the presence of beta dose for $H_p(0,07)$ whole body dosemeters

The requirements, method of test, and interpretation of the results stated in 11.7.2 apply for angles of incidence of 0°, see line 13 of Table 10. For angles of incidence of $\alpha = \pm 45°$ the response values shall be measured and stated.

12 Response to mixed irradiations (dosimetry system)

12.1 Requirements

The following requirement is fulfilled for dosimetry systems using only linear combinations or linear optimizations to obtain the signal and finally the indicated value, this requirement is fulfilled and no tests are required (the algorithm is an additive one).

Otherwise, e.g. if any branching or decision points from which on different methods (or equations or corrections) are used in the algorithm, the test shall be performed in order to check the evaluation algorithm of the dosimetry system for mixed irradiations. Mixed irradiation means that a dosemeter is irradiated with two portions of dose equivalent with different radiation qualities or other conditions. The difference in the radiation qualities or other conditions can be

a) a difference in the dose values, and / or
b) a difference in the value of one specific influence quantity (for example different energy and angle of radiation incidence), or
c) a different type of radiation if the dosimetry is tested with respect to more than one type of radiation.

Requirement: The relative response to mixed irradiation shall be within the range of response weighted with the respective dose values.

NOTE 1 This requirement ensures that the results of the test according to this document are also valid if the dosemeter is irradiated with broad spectra and/or mixtures of several radiation qualities.

NOTE 2 A radiation quality in this context is given by the notation according to ISO 4037 or ISO 6980 and the angle of incidence, for example N-30 and 45° angle of incidence.

NOTE 3 A dosimetry system with a non-additive evaluation algorithm can have, although it is in line with this document, the following characteristic: Two dosemeters (A and B) are irradiated with the same dose equivalent (for example 20 mSv) of one radiation quality (for example ^{137}Cs, 0°). Afterwards, dosemeter A is irradiated additionally with another radiation quality (for example 2 mSv, N-40, 0°). The indicated value of dosemeter A (for example 21 mSv) can be smaller than the one of dosemeter B (for example 22 mSv). For both dosemeters, the relative response is within the required range from 0,71 up to 1,67 (i.e. the requirement of 11.5.1 is fulfilled), but the indicated value is not additive.

12.2 Method of test

12.2.1 General

This test has to be performed via calculations using the signals of the dosemeter elements and the evaluation algorithm of the dosimetry system. Therefore, the testing laboratory needs access to the evaluation algorithm and the signals S_g of the dosemeters' elements.

12.2.2 Preparation of the test

The relative responses of the signals of the dosemeter elements gained during the tests according to 11.5, 11.6, and 11.7 shall be used. All radiation qualities listed in 11.5.1.2, 11.6.1.2, 11.6.2.2, 11.7.1.2, and 11.7.2.2 (depending on the type of dosemeter) and all angles of incidence from 0° up to the maximum rated angle in steps of 15° shall be taken into account. In case the dosemeter badge is not symmetrical four different directions (up, down, left, and right) shall be taken into account for every angle of incidence.

In case the relative responses of the signals of the dosemeter elements are not available for all radiation qualities and angles of incidence, these values can be determined by measurements or via Monte Carlo methods, the latter having to be validated by measurements.

In order to make sure that the evaluation algorithm supplied by the manufacturer is correct, the following test shall be done for a few radiation qualities for which irradiations were performed during the tests according to subclause 11.5, 11.6, and 11.7: The indicated value G_K evaluated by the dosimetry system shall be compared to the corresponding indicated value $f(S_{g,K})$ calculated using the signals $S_{g,K}$ of the $g = 1..b$ detector elements and the evaluation algorithm. The values have to be equal, otherwise the manufacturer shall deliver the correct function $f(S_g)$ for the evaluation of the indicated value.

12.2.3 Practical test

Mixed irradiations using the two radiation qualities K and L can be simulated by calculating the sum of the signals $S_{g,K} + S_{g,L}$ for each detector element g. From this sum, the indicated value $G_{K+L} = f(S_{g,K} + S_{g,L})$ for the mixed irradiation condition K+L with the conventional quantity dose value $C_{K+L} = C_K + C_L$ shall be calculated. The indicated value $G_{K+L} = f(S_{g,K} + S_{g,L})$ shall be determined for any possible combination of two radiation qualities K and L with different energy and angle of incidence within the rate range. For every combination of K and L, the ratio of C_K to C_L shall take the following values: 1:9, 2:8, .. up to 9:1 (nine different ratios). The total dose shall be within the standard test conditions, see line 1 of Table 7.

The relative response shall be calculated according to $r = \frac{G_{K+L}}{C_{K+L}} \cdot \frac{C_{r,0}}{G_{r,0}}$ for every combination described above. In Annex F, a computational method to perform all these calculations is described.

NOTE As an example, the rated range goes for photons from 33 keV up to 1,25 MeV and from 0° up to ± 60° and for betas from 0,24 MeV up to 0,8 MeV and from 0° up to ± 60°. According to subclauses 11.7.1.2 and 11.7.2.2 nine photon radiation qualities and two beta radiation qualities are involved. In addition, 17 different angles of incidence have to be considered: 0°, 15°, 30°, 45°, and 60°, the latter four from four different directions (up, down, left, right) as the dosemeter badge is assumed not to be symmetrical in any direction. In summary, (9+2) energies times 17 angles of incidence result in 187 contributions of different radiation qualities. The combination of each contribution with each other leads to 187·186/2 = 17 391 combinations. 17 391 combinations times 9 dose ratios result in 15 6519 types of signals to get the indicated value.

12.3 Interpretation of the results

All the calculated relative responses shall be within the permitted variation of the response. In case different response ranges are required for the different radiation qualities K and L, the range of response weighted with the respective dose values, C_K and C_L, shall be applied. The weighted response shall be calculated as follows: The response ranges for the radiation qualities K and L, $r_{min,K}$ .. $r_{max,K}$ and $r_{min,L}$ .. $r_{max,L}$, shall be combined to the weighted limits for the response values $r_{min,w} = \frac{r_{min,K} \cdot C_K + r_{min,L} \cdot C_L}{C_K + C_L}$ and $r_{max,w} = \frac{r_{max,K} \cdot C_K + r_{max,L} \cdot C_L}{C_K + C_L}$.

EXAMPLE:

$r_{min,K}$ = 0,67 & $r_{max,K}$ = 2,00 and
$r_{min,L}$ = 0,71 & $r_{max,L}$ = 1,67 with
C_K = 2 mSv and C_L = 8 mSv.

This results in $r_{min,w} = \frac{0{,}67 \cdot 2\,\text{mSv} + 0{,}71 \cdot 8\,\text{mSv}}{10\,\text{mSv}} = 0{,}70$ and $r_{max,w} = \frac{2{,}0 \cdot 2\,\text{mSv} + 1{,}67 \cdot 8\,\text{mSv}}{10\,\text{mSv}} = 1{,}74$.

In that case the requirement of 12.1 is considered to be met.

13 Environmental performance requirements and tests

13.1 General

13.1.1 General requirement

The influence quantities dealt with in this clause are of type F and/or type S. Therefore, two different requirements are valid for each influence quantity: One as if it was of type F (the range of relative response, r, is limited) and the other as if it was of type S (the deviation, D, is limited).

For the reader, only requirements according to a usual indoor use are given (varying temperature and light exposure, for example heating behind a large window due to sunlight).

13.1.2 General method of test

As the tests described in this clause are performed using rather low doses such as $7 \cdot H_{low}$ the consideration of the natural background radiation is of special importance, see 5.2.4.

Three different situations may occur:

a) In case it is not clear whether the influence quantity acts as type F or as type S, the conventional quantity value of the dose equivalent shall be $7 \cdot H_{low}$ if not stated otherwise in the respective subclause. For every group, n (≥ 6) dosemeters shall be irradiated. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the dosemeters may be irradiated at a higher dose equivalent if it is assumed that this is a type F influence quantity. Otherwise, the number of dosemeters shall be increased, see Clause A.1.

NOTE As stated above, also the influence quantities that may be of type S are limited by a maximum permitted value for the variation of the response. As the conventional quantity value of the dose equivalent is $7 \cdot H_{low}$, a change of the response by 10 % is equivalent to a deviation of $0{,}7 \cdot H_{low}$. Therefore, by this method of test, it is simultaneously ensured, that the deviation and the variation of the response from unity are not larger than the figures given above: $0{,}7 \cdot H_{low}$ and 10 %, respectively.

b) In case the influence quantity acts as type F, the conventional quantity value of the dose equivalent shall be at least $10 \cdot H_{low}$ if not stated otherwise in the respective subclause. For every group, n (≥ 6) dosemeters shall be irradiated. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the dosemeters may be irradiated at a higher dose equivalent and / or the number of dosemeters shall be increased, see Clause A.1.

c) In case the influence quantity acts as type S, the conventional quantity value of the dose equivalent shall be $7 \cdot H_{low}$ if not stated otherwise in the respective subclause. For every group, n (≥ 6) dosemeters shall be irradiated. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the number of dosemeters shall be increased, Clause A.1.

13.2 Ambient temperature and relative humidity (dosemeter)

13.2.1 General

The influence quantity dealt with in 13.2 is assumed to be of type F or of type S.

13.2.2 Requirements

The relative response and the deviation due to a change of the ambient temperature and relative humidity within their rated ranges shall not exceed the values given in line 1 of Table 14.

13.2.3 Method of test

For this test, three groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the three groups after the irradiation:

Group 1: reference group: the temperature and the relative humidity shall be at standard test conditions, see Table 7.

Group 2: the dosemeters shall be exposed to the lower extreme value of the rated range of the temperature. The relative humidity does not have to be controlled.

Group 3: the dosemeters shall be exposed to the upper extreme value of the rated range of the temperature and the upper extreme value of the rated range of the relative humidity (not condensing).

The duration of exposure shall be one week. As shortly as possible, but not shorter than allowed by the instructions of use, the dosemeters shall be read out.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.2.4 Interpretation of the results

If, for every group, the inequality $r_{min} \leq \left(\frac{\overline{G}_i}{\overline{G}_1} \pm U_{com} \right) \leq r_{max}$ (for type F influence quantities) or the inequality $\left| \overline{G}_i - \overline{G}_1 \pm U_{com} \right| \leq D_{max}$ (for type S influence quantities) is valid, then the requirements of 13.2.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 1 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.3 Light exposure (dosemeter)

13.3.1 General

The influence quantity dealt with in 13.3 is assumed to be of type F or of type S.

13.3.2 Requirements

The relative response and the deviation due to a change of the light exposure within its rated range shall not exceed the values given in line 2 of Table 14.

13.3.3 Method of test

For this test, two groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the two groups after the irradiation:

Group 1: reference group: the dosemeters shall be maintained at normal daylight in the shadow.

Group 2: the dosemeters shall be exposed to the maximum value within the rated range of light exposure for one week. During this test, the temperature shall be between 15 °C and 25 °C. A water cooling is recommended as the light source usually produces a lot of thermal energy.

To produce, for example, an effective cumulative integrated irradiance of 1 000 W/m^2 in the complete range of wavelengths at the test plane, use an apparatus which produces light whose spectrum corresponds to that of bright sunlight: at least 45 W/m^2 in the range of wavelengths between 300 nm and 400 nm and at least 630 W/m^2 in the range of wavelengths between 400 nm and 900 nm (values taken from the AM 1.5 spectrum in IEC 60904-3).

If 45 W/m^2 and 630 W/m^2 (in the respective ranges of wavelengths) cannot be attained the irradiance can be decreased by up to a factor of 2, however, the exposure time then has to be increased by the same factor.

NOTE A reference solar spectral irradiance distribution is given in IEC 60904-3.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.3.4 Interpretation of the results

If the inequality $r_{\text{min}} \leq \left(\frac{\overline{G}_2}{\overline{G}_1} \pm U_{\text{com}} \right) \leq r_{\text{max}}$ (for type F influence quantities) or the inequality $\left| \overline{G}_2 - \overline{G}_1 \pm U_{\text{com}} \right| \leq D_{\text{max}}$ (for type S influence quantities) is valid, then the requirements of 13.3.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 2 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.4 Dose build-up, fading and self-irradiation (dosemeter)

13.4.1 General

The influence quantity dealt with in 13.4 (time) is assumed to be of type F and type S.

13.4.2 Requirements

The relative response and the deviation due to dose build up, fading and self-irradiation shall not exceed the values given in line 3 of Table 14.

13.4.3 Method of test

For this test, three groups of dosemeters shall be used.

Groups 1 to 3 consisting of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2. The irradiations should be performed at different times so that all readings take place at the same time (in order to exclude possible effects due to reader instabilities during the test). If all irradiations are performed at the same time effects due to reader instabilities need to be corrected for.

Further information regarding the method of test is given in 13.1.2.

Treatment of the three groups after the irradiation:

Group 1 shall be read out 24 h (or as soon as possible) after the irradiation.

Group 2, reference group, shall be read out one week after the irradiation.

Group 3 shall be read out after the maximum rated measurement time t_{max} after the irradiation.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.4.4 Interpretation of the results

If for groups 1 to 3 the inequality $r_{min} \leq \left(\frac{\overline{G}_i}{\overline{G}_2} \pm U_{com} \right) \leq r_{max}$ (for type F influence quantities) or the inequality $\left| \overline{G}_i - \overline{G}_2 \pm U_{com} \right| \leq D_{max}$ (for type S influence quantities) is valid, then the requirements of 13.4.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 3 of Table 14.

U_{com} and U_m are calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively, and formula (A.3), respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.5 Sealing (dosemeter)

The manufacturer shall state the precautions to be taken to prevent the ingress of moisture, and describe the tests and results used to demonstrate the effectiveness of the sealing.

This requirement is essential for extremity dosemeters as they usually have to be disinfected using liquids.

13.6 Reader stability (reader)

13.6.1 General

The influence quantity dealt with in 13.6 (time) is assumed to be of type F or of type S.

13.6.2 Requirements

The relative response and the deviation due to reader stability shall not exceed the values given in line 5 of Table 14 over the maximum rated measurement time t_{max}.

13.6.3 Method of test

For this test, three groups of n (≥ 6) dosemeters shall be used.

Group 1 shall be irradiated at the beginning of the type test and read out one week later.

Group 2 shall be irradiated to the same dose as group 1 after half of the maximum rated measurement time $t_{max}/2$ and read out one week later.

Group 3 shall be irradiated to the same dose as groups 1 and 2 after the maximum rated measurement time t_{max} and read out one week later.

Further information regarding the method of test is given in 13.1.2.

For every group, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

13.6.4 Interpretation of the results

If, for every group, the inequality $r_{min} \leq \left(\frac{\overline{G_i}}{\overline{G_1}} \pm U_{com} \right) \leq r_{max}$ (for type F influence quantities) or the inequality $\left| \overline{G_i} - \overline{G_1} \pm U_{com} \right| \leq D_{max}$ (for type S influence quantities) is valid, then the requirements of 13.6.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 5 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.7 Ambient temperature (reader)

13.7.1 General

The influence quantity dealt with in 13.7 may be of type S or of type F.

13.7.2 Requirements

The relative response and the deviation due to a change of the temperature within its rated range shall not exceed the values given in line 6 of Table 14.

In case it can be made sure by physical reasons that temperature does not have a significant effect on the indicated value then this test can be omitted.

13.7.3 Method of test

This test shall only be done in case a temperature range outside +15 °C and +25 °C is specified by the manufacturer.

For this test, two groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the two groups after the irradiation:

Group 1, reference group: the temperature of the reader shall be at standard test conditions (see Table 7) and the dosemeters shall be read out.

Groups 2: the temperature of the reader shall be at least 4 h at the highest temperature within the rated range. At the end of at least 4 h, the readout of the dosemeters shall be performed holding the given temperature.

For every group, the mean indicated value $\overline{G_i}$ and the standard deviation s_i shall be determined.

13.7.4 Interpretation of the results

If the inequality $r_{\text{min}} \leq \left(\frac{\overline{G_2}}{\overline{G_1}} \pm U_{\text{com}} \right) \leq r_{\text{max}}$ (for type F influence quantities) or the inequality $\left| \overline{G_2} - \overline{G_1} \pm U_{\text{com}} \right| \leq D_{\text{max}}$ (for type S influence quantities) is valid, then the requirements of 13.7.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 6 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.8 Light exposure (reader)

13.8.1 General

The influence quantity dealt with in 13.8 is usually of type S, it may be of type F.

In case it can be made sure by physical reasons that light does not have a significant effect on the indicated value then this test can be omitted.

13.8.2 Requirements

The relative response and the deviation due to a change of the light exposure within its rated range shall not exceed the values given in line 7 of Table 14.

13.8.3 Method of test

For this test, two groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the two groups after the irradiation:

The dosemeters shall not (or as minimally as possible) be exposed to the additional light source.

Group 1, reference group: the reader shall not be exposed to any additional light than the usual daylight in shadow and the dosemeters shall be read out.

Group 2: the outside parts of the reader near the seal of the photomultiplier or other light sensitive devices of the reader shall be exposed to the extreme value of light exposure (for example by placing a lamp close to the surface of the reader) within the rated range and the dosemeters shall be read out. During this test, the temperature shall be between 15 °C and

25 °C. Water cooling is recommended as the light source usually produces a lot of thermal energy.

To produce for example an effective cumulative integrated irradiance of 1 000 W/m^2 in the complete range of wavelengths at the test plane, use a device or an lamp which produces light whose spectrum corresponds approximately to that of bright sunlight: at least 45 W/m^2 in the range of wavelengths between 300 nm and 400 nm and at least 630 W/m^2 in the range of wavelengths between 400 nm and 900 nm (values taken from the AM 1.5 spectrum in IEC 60904-3).

NOTE A reference solar spectral irradiance distribution is given in IEC 60904-3.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.8.4 Interpretation of the results

If the inequality $r_{\text{min}} \leq \left(\frac{\overline{G}_2}{\overline{G}_1} \pm U_{\text{com}} \right) \leq r_{\text{max}}$ (for type F influence quantities) or the inequality $\left| \overline{G}_2 - \overline{G}_1 \pm U_{\text{com}} \right| \leq D_{\text{max}}$ (for type S influence quantities) is valid, then the requirements of 13.8.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 7 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

13.9 Primary power supply (reader)

13.9.1 General

The influence quantity dealt with in 13.9 is usually of type F, it may be of type S.

13.9.2 Requirements

The relative response and the deviation due to a change of the power supply voltage and frequency within its rated range shall not exceed the values given in line 8 of Table 14.

In addition, the coefficient of variation shall fulfil the requirements specified in 11.2.

13.9.3 Method of test

For this test, five groups of n (≥ 6) dosemeters shall be exposed to a reference source, see 13.1.2.

Treatment of the five groups after the irradiation:

The dosemeters shall be read out under the following conditions:

Group 1, reference group: nominal power supply voltage and frequency

Group 2: minimum voltage and minimum frequency within their rated ranges

Group 3: maximum voltage and minimum frequency within their rated ranges

Group 4: minimum voltage and maximum frequency within their rated ranges

Group 5: maximum voltage and maximum frequency within their rated ranges

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined.

13.9.4 Interpretation of the results

If, for every group, the inequality $r_{\text{min}} \leq \left(\frac{\overline{G}_i}{\overline{G}_1} \pm U_{\text{com}} \right) \leq r_{\text{max}}$ (for type F influence quantities) or the inequality $\left| \overline{G}_i - \overline{G}_1 \pm U_{\text{com}} \right| \leq D_{\text{max}}$ (for type S influence quantities) is valid, then the requirements of 13.9.2 are considered to be met. The values for r_{min}, r_{max}, and D_{max} are given in line 8 of Table 14.

U_{com} is calculated according to formula (A.5), Example 1 or Example 2, for differences or ratios, respectively. These calculations presume that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

14 Electromagnetic performance requirements and tests (dosimetry system)

14.1 General

Special precautions shall be taken in the design of a dosimetry system to ensure proper operation in the presence of electromagnetic disturbances. Electromagnetic disturbance are mainly influence quantities of type S.

Tests shall be performed for all components of the dosimetry system containing electronic components. This is usually, at least, the case for readers but may also be the case for badges, e.g. in case of a direct ion storage (DIS) dosemeter.

14.2 Requirements

The absolute value of the deviation due to electromagnetic disturbances shall not exceed $0{,}7 \cdot H_{\text{low}}$ for every single influence quantity, see Table 15. Exception: The absolute value of the deviation may be larger than $0{,}7 \cdot H_{\text{low}}$ for one indicated value, if the dosimetry system delivers an error message assigning that this value is faulty. In addition, the dosimetry system shall not lose more than one indicated value, see 10.5.

For all influence quantities, the mandatory ranges are taken from IEC 61000-6-2.

The tests in lines 4, 5, and 7 of Table 15 need not to be done for readers for which the manufacturer declares that either the respective influence quantity does not affect the indicated value by more than $0{,}7 \cdot H_{\text{low}}$ during readout of dosemeters or the effect is recognized and accompanied by an error message (at most one, see above) or the effect is corrected for (for example by means of software). This declaration shall contain the necessary evidence. This evidence can be a physical reason why the device is not affected by the electromagnetic disturbance or why the electromagnetic disturbance is not present. This evidence has to be stated for each electromagnetic disturbance separately. One example is, that no mobile phones are allowed in the room of the reader.

The test in line 7 of Table 15 shall be conducted from at least two sides of the device under test and with both polarizations of the radio-frequency field for

– badges containing electronic components at 30 V/m with a frequency sweep and
– for all other parts of the dosimetry system containing electronic components such as the reader at 30 V/m with at least the frequencies stated in note e of Table 15; if that test leads to a failure then a test at 10 V/m shall be conducted from all six sides of the device under test.

14.3 Method of test

As the tests described in this clause are performed using rather low doses such as $7 \cdot H_{low}$ the consideration of the natural background radiation is of special importance, see 5.2.4.

For the test according to lines 1 to 6 of Table 15 seven groups of n (≥ 10) dosemeters and for the test according to line 7 of Table 15 one group of n (≥ 60) dosemeters shall be exposed to a reference source with a dose equivalent of $7 \cdot H_{low}$. For those influence quantities for which a declaration of the manufacturer is available, see 14.2, no dosemeters need to be irradiated.

Group 1, reference group: no electromagnetic influences shall be present. To ensure this, appropriate filters, shieldings and so on shall be applied.

Groups 2, 6 and 8: in case the dosemeters contain any electric parts that may be sensitive to electromagnetic disturbances (for example a DIS dosemeter), the dosemeters shall be exposed to the influence quantities according to lines 1, 5 and 7 of Table 15 prior to their readout. The radio frequency radiation shall be applied with the frequencies stated in footnote e to Table 15.

Group 1 shall be read out without any electromagnetic influences.

Groups 2 to 8 shall be read out while the different electromagnetic influences are applied to the reader in accordance with the standards of the IEC 61000-4 series as given in Table 15. Each electromagnetic influence shall be applied for the duration of the readout of one dosemeter. If possible, the output of the reader (for example glow curve) shall be observed. Without error message, no abnormal characteristics (for example spikes in a glow curve that cause non-negligible doses) shall occur.

For every group, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined. In case any indicated values were marked by the dosimetry system as faulty, these values shall be excluded from the determination of $\overline{G}_i$ and s_i.

14.4 Interpretation of the results

If, for every group, the inequality $\left|\overline{G}_i - \overline{G}_1 \pm U_{com}\right| \leq 0{,}7 \cdot H_{low}$ is valid and if for the tests with criterion A no single indicated value is lost, and if for the tests with criterion B or C at most one indicated value per influence quantity is lost, then the requirement of 14.2 is considered to be met.

U_{com} is calculated according to formula (A.5). This calculation presumes that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

NOTE The maximum is built over the two possibilities $\left|\overline{G}_i - \overline{G}_1 + U_m\right|$ and $\left|\overline{G}_i - \overline{G}_1 - U_m\right|$.

15 Mechanical performance requirements and tests

15.1 General requirement

Mechanical disturbances are mainly influence quantities of type S, they may be of type F. For the sake of simplification, the mathematical treatment is done as if all influence quantities were of type S.

The absolute value of the deviation due to mechanical disturbances shall not exceed $0{,}7 \cdot H_{low}$ for every single influence quantity (see Table 16). Exception: The absolute value of the deviation may be larger than $0{,}7 \cdot H_{low}$ for one indicated value, if the dosimetry system delivers an error message assigning that a specific indicated value is faulty.

It is not allowed to have more than one indicated value lost or accompanied by an error message due to any occurrence of abnormal operation, see 10.5.

15.2 Drop (dosemeter)

15.2.1 Requirements

A dosemeter shall be able to withstand drops from a height of 1,0 m onto a flat and hard surface made of concrete or steel (IEC 60068-2-31) without the deviation exceeding $\pm\, 0{,}7 \cdot H_{low}$ after the drop. These tests shall be on each face of the dosemeter.

The dosemeter shall not be damaged, neither on the inside (for example loosening of filter material) nor on the outside.

15.2.2 Method of test

As the tests described in this clause are performed using rather low doses such as $7 \cdot H_{low}$ the consideration of the natural background radiation is of special importance, see 5.2.4.

For these tests two groups of n (≥ 6) dosemeters shall be exposed to a reference source with a dose equivalent of $7 \cdot H_{low}$. In case the coefficient of variation of the indicated value is too large to judge whether the requirements are met or not, the dosemeters may be irradiated at a higher dose equivalent in case the influence quantity acts as a type F influence quantity. Otherwise, the number of dosemeters should be increased, see Clause A.1.

Group 1: reference group.

Group 2: each of the dosemeters shall be subjected to a test consisting of drops on each of the 6 faces of the dosemeter.

The dosemeters shall be inspected and the physical condition documented, for example whether the filter materials are fixed and in position.

After all the tests, the dosemeters shall be read out and the indicated values be determined.

For groups 1 and 2, the mean indicated value $\overline{G}_i$ and the standard deviation s_i shall be determined. In case any indicated values were marked by the dosimetry system as faulty, these values shall be excluded from the determination of $\overline{G}_i$ and s_i.

NOTE As stated above, also the influence quantities that may be of type F are limited by a maximum permitted value for the deviation: $\pm\, 0{,}7 \cdot H_{low}$. As the conventional quantity value of the dose equivalent is $7 \cdot H_{low}$, a deviation of $\pm\, 0{,}7 \cdot H_{low}$ is equivalent to a change of the response of ± 10 %. Therefore, by this method of test, it is simultaneously ensured, that the deviation and the variation of the response from unity are not larger than the figures given above ($\pm\, 0{,}7 \cdot H_{low}$ and ± 10 %, respectively).

15.2.3 Interpretation of the results

If for the two groups the inequality $\left|\overline{G}_2 - \overline{G}_1 \pm U_{com}\right| \leq 0{,}7 \cdot H_{low}$ is valid, then the requirement of 15.2.1 is considered to be met.

U_{com} is calculated according to formula (A.5). This calculation presumes that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com}.

16 Documentation

16.1 Type test report

At the request of the customer, the manufacturer shall make available the report on the type tests performed according to the requirements of this document.

16.2 Certificate issued by the laboratory performing the type test

A certificate shall be issued to each dosimetry system, providing at least the following information:

Dosimetry system in general:

– manufacturer's name or registered trade mark (if the system is manufactured as a whole);
– type of dosimetry system and principle of operation;
– statement that the equipment is tested according to this document and that the requirements are fulfilled;
– name of the software of the dosimetry system and identification number (see 10.3);
– if the evaluation algorithm is not additive, a comment according to Note 3 of 12.1.

Reader:

– manufacturer's name or registered trade mark;
– type of the reader and serial number of the reader under test.

Dosemeter:

– manufacturer's name or registered trade mark;
– type of dosemeter and serial numbers of the dosemeters under test;
– type of detector or detectors;
– types of radiation the dosemeter is intended to measure.

Dosimetric characteristics:

– measuring quantity;
– measuring range and variation of the response due to non-linearity;
– coefficient of variation depending on the dose equivalent;
– maximum rated measurement time;
– relative response as a function of radiation energy and angle of incidence (for both beta and photon radiation);
– rated ranges of all other influence quantities and the corresponding variation of the response or deviation (see 7.2 to 7.6, an example is given in 7.7).

Table 6 – Symbols

Symbol	Meaning	Unit
α	Angle of radiation incidence	Degrees
α_{max}	Maximum value of the rated range of the angle of radiation incidence	Degrees
b	Number of signals of one dosemeter that are used to evaluate the indicated dose value	—
C	Conventional quantity dose value	Sv
C_i	Conventional quantity dose value of irradiation group i	Sv
C_K	Conventional quantity value of (delivered) dose equivalent for irradiation condition K	Sv
C_L	Conventional quantity value of (delivered) dose equivalent for irradiation condition L	Sv
C_r	Conventional quantity value of (delivered) dose equivalent under reference conditions: that means, all influence quantities have their reference value, except the value of the dose equivalent is different from its reference condition: $C_r \neq C_{r,0}$	Sv
$C_{r,0}$	As C_r but only for reference dose equivalent, see Table 7, line 1	Sv
ΔG	Change in indication caused by subsequent and mixed exposure, see 11.9	Sv
d	Depth in ICRU 4-element or soft tissue. Recommended depths are 10 mm, 3 mm, and 0,07 mm	m
D	Deviation	Sv
D_{EMC}	Deviation due to electromagnetic disturbances	Sv
D_{max}	Maximum permitted variation of deviation due to an influence quantity	Sv
D_{mech}	Deviation due to mechanical disturbances	Sv
D_p	Deviation due to influence quantity no. p of type S; $p = 1..l$	Sv
E_{beta}	Beta energy	keV or MeV
E_{ph}	Photon energy	keV or MeV
$f(S_1,...S_b) = f(S_g)$	Function representing the evaluation algorithm inside the dosimetry system to evaluate the indicated value	Sv
g	Designator for a specific signal delivered from one dosemeter; $g = 1..b$	—
G	Indicated value	Sv
$\overline{G_i}$	Mean indicated value of group i	Sv
$\overline{G}'_i$	Mean indicated value of group i prime (background indications subtracted)	Sv
G_j	Indicated value of the j-th dosemeter of several dosemeters irradiated equally; $j = 1..n$	Sv
$G_{j,i}$	Indicated value of the j-th dosemeter of group i	Sv
G_K	Indicated value due to a single irradiation with C_K	Sv
G_{K+L}	Indicated value due to a combined irradiation with $C_K + C_L$	Sv
G_L	Indicated value due to a single irradiation with C_L	Sv
G_r	Indicated value of a dosemeter irradiated with C_r	Sv
$G_{r,0}$	Indicated value of a dosemeter irradiated with $C_{r,0}$	Sv
$h_{pK}(d;R,\alpha)$	Conversion coefficient from air kerma to the personal dose equivalent at a depth d for the radiation series R	Sv
$h'_K(d;R,\alpha)$	Conversion coefficient from air kerma to the directional dose equivalent at a depth d for the radiation series R	Sv
H	Synonym for dose equivalent, may be $H_p(10)$, $H_p(0,07)$ or $H^*(10)$	Sv
H_{low}	Lower dose limit of the range of measurement	Sv
H_{up}	Upper dose limit of the range of measurement	Sv
$H^*(10)$	Ambient dose equivalent at a depth 10 mm	Sv
$H^*(d)$	Ambient dose equivalent at a depth d	Sv

Symbol	Meaning	Unit
$H_p(0,07)$	Personal dose equivalent at a depth 0,07 mm	Sv
$H_p(3)$	Personal dose equivalent at a depth 3 mm	Sv
$H_p(10)$	Personal dose equivalent at a depth 10 mm	Sv
$H_p(d)$	Personal dose equivalent at a depth d	Sv
i	Designator for a group subjected to a specific influence quantity	—
j	Designator for a specific dosemeter out of n dosemeters irradiated equally	—
k	Coverage factor	—
K	Symbol of radiation condition K, e. g. 3 mSv, N-80 and 60°	—
l	Number of influence quantities of type S	—
L	Symbol of radiation condition L, e. g. 4 mSv, S-Co and 0°	—
m	Number of influence quantities of type F	—
M	Measured value	Sv
n	Number of dosemeters in one group that are equally irradiated	—
N	Pointer to the table entry containing the signals (N's row)	—
N_0	(Reference) calibration coefficient	—
N_{max}	Number of rows in the table containing the signals	—
p	Designator for a specific influence quantity of type S out of l type S influence quantities	—
q	Designator for a specific influence quantity of type F out of m type F influence quantities	—
r	Relative response	—
$r_{E,\alpha}$	Relative response due to energy and angle of incidence	—
r_{env}	Relative response due to environmental influences	—
r_{max}	Maximal permitted value of the relative response due to an influence quantity	—
$r_{max,w}$	Maximal permitted value of the relative response due to an influence quantity for a mixed irradiation	—
r_{min}	Minimal permitted value of the relative response due to an influence quantity	—
$r_{min,w}$	Minimal permitted value of the relative response due to an influence quantity for a mixed irradiation	—
r_n	Relative response due to non-linearity	—
r_q	Relative response due to influence quantity no. q of type F; q = 1..m	—
R	Symbol of radiation series R, for example, N series or S series	—
R	Response	—
R_0	Reference response	—
R_n	Response under reference conditions, except the value of the dose equivalent is different from reference conditions	—
s	Standard deviation	As quantity
s_i	Standard deviation of group i	As quantity
S	Signal of a detector; from one detector more than one signal can be derived	Depending
S_g	Signal number g of a dosemeter; g = 1..b	Depending
$S_{g,K}$	Signal number g due to the radiation quality K	Depending
$S_{g,L}$	Signal number g due to the radiation quality L	Depending
t_{max}	Maximum rated measurement time	Month
t_{n-1}	Students t-factor for n measurements	—
U	Expanded uncertainty	As quantity

Symbol	Meaning	Unit
$U_{C,com}$	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
$U_{C,rel}$	Relative expanded uncertainty of the conventional quantity value	—
U_{com}	Expanded uncertainty of a combined quantity. This is equivalent to the half-width of the confidence interval about the combined quantity at a confidence level of 95 %. See Annex A, formula (A.5)	As quantity
U_m	Expanded uncertainty of a mean value. This is equivalent to the half-width of the confidence interval about a mean at a confidence level of 95 %	As quantity
U_{rel}	Relative expanded uncertainty	—
V	Coefficient of variation	As quantity

Table 7 – Reference conditions and standard test conditions

Quantity to be measured; influence quantity	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Reference dose equivalent $C_{r,0}$ for $H_p(10)$, $H^*(10)$, $H_p(3)$, $H'(3)$, $H_p(0,07)$ and $H'(0,07)$	3 mSv 10 mSv	1 mSv to 10 mSv 3 mSv to 30 mSv
Photon radiation energy for $H_p(10)$, $H^*(10)$, $H_p(3)$, $H'(3)$, $H_p(0,07)$, and $H'(0,07)$	S-Cs (ISO 4037) [a]	S-Cs (ISO 4037) [a]
Beta radiation energy for $H_p(3)$, $H'(3)$, $H_p(0,07)$, and $H'(0,07)$	$^{90}Sr/^{90}Y$ (ISO 6980) [a,b]	$^{90}Sr/^{90}Y$ (ISO 6980) [a,b]
Reference point of a dosemeter	See 3.34	See 3.34
Reference orientation	See 3.33	See 3.33
Angle of incidence of radiation	Reference direction given by the manufacturer	Reference direction ± 2°
Ambient temperature	20 °C	15 °C to 25 °C [c]
Relative humidity	65 %	50 % to 75 % [c]
Atmospheric pressure	101,3 kPa	86,0 kPa to 106,6 kPa [c]
Power supply voltage	Nominal power supply voltage	Nominal power supply voltage ± 1 %
Frequency	Nominal frequency	Nominal frequency ± 1 %
AC power supply waveform	Sinusoidal	Sinusoidal with total harmonic distortion less than 5 %
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the induction due to the earth's magnetic field
Dosemeter controls	Set up for normal operation	Set up for normal operation
Radiation background	Ambient dose equivalent rate of 0,1 μSv/h or less if practical	Less than ambient dose equivalent rate of 0,25 μSv/h
Contamination by radioactive elements	Negligible	Negligible

[a] Obey the third paragraph in 11.1 regarding dosimetry systems intended to measure both photon and beta radiation.

[b] For beta dosemeters, alternatively a photon radiation quality may be chosen as reference radiation quality.

[c] The actual values of theses quantities at the time of test shall be stated. The conventional quantity value of the dose equivalent shall be corrected for the deviation from reference conditions. A lower limit of pressure of 70 kPa may be permitted at high altitudes.

Table 8 – Performance requirements for $H_p(10)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	$H < 0{,}1$ mSv $0{,}1$ mSv $\leq H < 1{,}1$ mSv $H \geq 1{,}1$ mSv	15 % (16 – H / 0,1 mSv) % 5 %	11.2
7	Relative response due to non-linearity	0,1 mSv $\leq H \leq$ 1 Sv	–13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	80 keV to 1,25 MeV and 0° to ± 60°	r_{min} = 0,71 to r_{max} = 1,67	11.5.1
10	Relative response due to mean beta radiation energy	0,8 MeV	Indicated value maximal 10 % of $H_p(0{,}07)$ dose equivalent	11.5.2
11	As in lines 9 and 10 but new reference direction opposite to that one used	See lines 9 and 10, if no statement by the manufacturer	See lines 9 and 10, if no statement by the manufacturer	8.4 e)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from α_{max} to 180°–α_{max}	Indication less than 2 times of indication due to irradiation free in air from the front	11.8
13	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
14	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
15	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
16	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	$\pm$ 0,7·H_{low} at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in$ [0,6 .. 1,4] ➔ $r \in$ [1/1,4 .. 1/0,6] = [0,71 .. 1,67]				

Table 9 – Performance requirements for $H_p(3)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	$H <$ 0,3 mSv 0,3 mSv $\leq H <$ 3,3 mSv $H \geq$ 3,3 mSv	15 % (16 – H / 0,3 mSv) % 5 %	11.2
7	Relative response due to non-linearity	0,3 mSv $\leq H \leq$ 1 Sv	–18 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum 20 Sv Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	30 keV to 1,25 MeV and 0° to ± 60°	r_{min} = 0,71 to r_{max} = 1,67	11.6.1
10	Only if the dosemeter is specified for beta radiation: Relative response, r, due to mean beta radiation energy and angle of incidence	A: 0,8 MeV and 0° to ± 60° B: 0,24 MeV	A: r_{min} = 0,71 to r_{max} = 1,67 B: Indicated value maximal 10 % of $H_p(0,07)$ dose equivalent	11.6.2
11	As in lines 9 and 10 but new reference direction opposite to that one used	See lines 9 and 10, if no statement by the manufacturer	See lines 9 and 10, if no statement by the manufacturer	8.4 e)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from α_{max} to 180°–α_{max}	Indication less than 2 times of indication due to irradiation free in air from the front	11.8
13	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
14	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
15	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
16	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7·H_{low} at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in$ [0,6 .. 1,4] ➔ $r \in$ [1/1,4 .. 1/0,6] = [0,71 .. 1,67]				

Table 10 – Performance requirements for $H_p(0,07)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	$H < 1$ mSv 1 mSv $\leq H <$ 11 mSv $H \geq 11$ mSv	15 % (16 – H / 1 mSv) % 5 %	11.2
7	Relative response due to non-linearity	1 mSv $\leq H \leq$ 3 Sv	–18 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum 20 Sv Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	30 keV to 250 keV and 0° to ± 60°	r_{min} = 0,71 to r_{max} = 1,67	11.7.1
10	Only if the dosemeter is specified for beta radiation: Relative response due to mean beta radiation energy and angle of incidence	0,24 MeV to 0,8 MeV and 0° to ± 60° for extremity dosemeters and 0,8 MeV and 0° to ± 45° for whole body dosemeters	r_{min} = 0,71 to r_{max} = 1,67 For whole body dosemeters: If not met, line 13 applies	11.7.2
11	As in lines 9 and 10 but new reference direction opposite to that one used	See lines 9 and 10, if no statement by the manufacturer	See lines 9 and 10, if no statement by the manufacturer	8.4 e)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from α_{max} to 180°–α_{max}	Indication less than 2 times of indication due to irradiation free in air from the front	11.8
13	For whole body dosemeters: Indication of the presence of beta dose	0,8 MeV at 0° angle of incidence	r_{min} = 0,71 to r_{max} = 1,67	11.9
14	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
15	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
16	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
17	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7·H_{low} at a dose of H = 7 H_{low}	15

Table 11 – Performance requirements for $H^*(10)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	H < 0,1 mSv 0,1 mSv ≤ H < 1,1 mSv H ≥ 1,1 mSv	15 % (16 – H / 0,1 mSv) % 5 %	11.2
7	Relative response due to non-linearity	0,1 mSv ≤ H ≤ 1 Sv	–13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	80 keV to 1,25 MeV and 0° to ±60° and 180° to (180°± 60°) and for environmental dosemeters from ± 60° to ± 120°	r_{min} = 0,71 to r_{max} = 1,67 and r_{min} = 0,67 to r_{max} = 2,00	11.5.1
10	Relative response due to mean beta radiation energy	0,8 MeV	Indicated value maximal 10 % of $H_p(0,07)$ dose equivalent	11.5.2
11	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
12	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
13	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
14	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7·H_{low} at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in$ [0,6 .. 1,4] ➔ $r \in$ [1/1,4 .. 1/0,6] = [0,71 .. 1,67]				

Table 12 – Performance requirements for $H'(3)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	$H < 0{,}3$ mSv $0{,}3$ mSv $\leq H < 3{,}3$ mSv $H \geq 3{,}3$ mSv	15 % (16 – H / 0,3 mSv) % 5 %	11.2
7	Relative response due to non-linearity	0,3 mSv $\leq H \leq$ 1 Sv	–13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	30 keV to 1,25 MeV and 0° to ± 60° and 180° to (180°± 60°) and for environmental dosemeters from ± 60° to ± 120°	r_{min} = 0,71 to r_{max} = 1,67 and r_{min} = 0,67 to r_{max} = 2,00	11.6.1
10	Only if the dosemeter is specified for beta radiation: Relative response due to mean beta radiation energy and angle of incidence	A: 0,8 MeV and 0° to ± 60° B: 0,24 MeV	A: r_{min} = 0,71 to r_{max} = 1,67 B: Indicated value maximal 10 % of $H_p(0{,}07)$ dose equivalent	11.6.2
11	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
12	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
13	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
14	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7 $\cdot H_{low}$ at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in$ [0,6 .. 1,4] ➔ $r \in$ [1/1,4 .. 1/0,6] = [0,71 .. 1,67]				

Table 13 – Performance requirements for $H'(0,07)$ dosemeters

Line	Characteristic under test	Main characteristics or mandatory measuring range or mandatory range of influence quantity	Performance requirement for the rated range	Clause/ Sub-clause
1	Capability of the dosimetry system	Measuring range; influence quantities; t_{max}; model function	To be documented by the manufacturer for the type test	7
2	Requirements to the design of the dosimetry system	Dose indication; information on reader, dosemeter and evaluation algorithm	To be documented by the manufacturer for the type test and checked during type test	8
3	Effects of radiation not intended to be measured	Response to thermal neutrons, ^{252}Cf and ^{252}Cf (D_2O-moderated)	Response to be stated by the manufacturer	8.7
4	Instruction manual	Information for correct use; information about the performance of the system	To be documented by the manufacturer for the type test and checked during type test	9
5	Software, data and interfaces	Authenticity of the software; correctness and integrity of data	To be documented by the manufacturer for the type test and checked during type test	10
6	Coefficient of variation, v	H < 1 mSv 1 mSv ≤ H < 11 mSv H ≥ 11 mSv	15 % (16 – H / 1 mSv) % 5 %	11.2
7	Relative response due to non-linearity	1 mSv ≤ H ≤ 3 Sv	–13 % to +18 %	11.3
8	Overload, after-effects, and reusability	10 times the upper limit of the measuring range: $10 \cdot H_{up}$, however at maximum 20 Sv. Reused dosemeters shall fulfil the requirements	Perception to be off-scale on the high end side of the measuring range, after-effects may not cause fault measurements and $v(H_{low})$ shall be according to line 6	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	30 keV to 250 keV and 0° to ± 60° and 180° to (180°± 60°) and for environmental dosemeters from ± 60° to ± 120°	r_{min} = 0,71 to r_{max} = 1,67 and r_{min} = 0,67 to r_{max} = 2,00	11.7.1
10	Only if the dosemeter is specified for beta radiation: Relative response due to mean beta radiation energy and angle of incidence	0,24 MeV to 0,8 MeV and 0° to ± 60°	r_{min} = 0,71 to r_{max} = 1,67	11.7.2
11	Response to mixed irradiations	Irradiation with different radiation qualities	Response within ranges of radiation qualities under test	12
12	Total effect due to environmental performance requirements	Temperature, light, time; for details, see Table 14	See Table 14	13
13	Deviation due to electromagnetic performance requirements	See Table 15	See Table 15	14
14	Deviation due to mechanical performance requirements	Drop; for details, see Table 16	± 0,7 · H_{low} at a dose of H = 7 H_{low}	15
NOTE The non-symmetrical borders of relative responses r are derived from symmetrical borders of correction factors ($1/r$), for example: ± 40 % for $1/r \in$ [0,6 .. 1,4] ➔ $r \in$ [1/1,4 .. 1/0,6] = [0,71 .. 1,67]				

Table 14 – Environmental performance requirements for dosemeters and readers

Line	Characteristic under test	Mandatory range of influence quantity	Maximum permitted variation of relative response [a] and deviation, D, [b] for the rated range	Clause/ Sub-clause
1	Relative response and deviation due to ambient temperature and relative humidity (dosemeter)	• Personal dosemeters: –10 °C to +40 °C • Environmental dosemeters: –20 °C to +50 °C and 10 % to 90 % relative humidity, not condensing	Type F: r_{min} = 0,83; r_{max} = 1,25 Type S: D_{max} = 1,4 H_{low} at a dose of H = 7 H_{low}	13.2
2	Relative response and deviation due to light exposure (dosemeter)	0 W/m^2 to 1 000 W/m^2 (spectrum corresponding to bright sunlight)	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low}	13.3
3	Dose build-up, fading and self-irradiation (dosemeter)	Maximum rated measurement time: $t_{max} \geq$ 1 month	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of Table 8 to Table 13	13.4
4	Sealing (dosemeter)	Ingress shall be prevented	Precautions to be stated	13.5
5	Relative response and deviation due to reader stability (reader)	Stability over t_{max}	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low}	13.6
6	Relative response and deviation due to ambient temperature (reader)	+15 °C to +25 °C for at least 4 h but long enough to ensure temperature equilibrium with the environment.	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of Table 8 to Table 13	13.7
7	Relative response and deviation due to light exposure (reader)	0 W/m^2 to 1 000 W/m^2 (spectrum corresponding to bright sunlight)	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of Table 8 to Table 13	13.8
8	Relative response and deviation due to a change in the primary power supply (reader)	Power supply voltage: –15 % to +10 % from nominal value (for example 110 V or 230 V) Frequency: –2 % to +2 % from nominal value (for example 50 Hz or 60 Hz)	Type F: r_{min} = 0,91; r_{max} = 1,11 Type S: D_{max} = 0,7 H_{low} at a dose of H = 7 H_{low} and for type F and type S $v(H_{low})$ according to line 6 of Table 8 to Table 13	13.9

[a] Valid in case the influence quantity is assumed to be of type F.

[b] Valid in case the influence quantity is assumed to be of type S.

Table 15 – Electromagnetic disturbance performance requirements for dosimetry systems according to Clause 14

Line	Influence quantity	Mandatory range of influence quantity	Criterion[a]	Test according to	Maximum permitted deviation, D, for the rated range at a dose of $H = 7\,H_{low}$
1	Electrostatic discharge	2 kV to ± 8 kV air discharge 2 kV to ± 4 kV contact discharge	B	IEC 61000-4-2	± 0,7 H_{low}
2	Conducted disturbances: fast transients	± 2 kV (a.c. and d.c.[b] power ports) ± 1 kV (signal ports) [b] ± 1 kV (functional earth ports) 5/50 ns (t_r/t_h) 5 kHz repetition frequency	B	IEC 61000-4-4	± 0,7 H_{low}
3	Conducted disturbances: surges	0,5 kV to ± 2 kV (a.c. power ports, line-to-earth) 0,5 kV to ± 1 kV (a.c. power ports, line-to-line) 0,5 kV to ± 0,5 kV (d.c. power ports) 0,5 kV to ± 1 kV (signal ports, line-to-earth) [c] 1,2/50 (8/20) µs (t_r/t_h)	B	IEC 61000-4-5	± 0,7 H_{low}
4	Conducted disturbances: radio-frequencies common mode	150 kHz to 80 MHz 10 V (rms, unmodulated) 80 % AM (1 kHz) (signal ports, a.c. power ports and functional earth ports)	A	IEC 61000-4-6	± 0,7 H_{low}
5	Power-frequency magnetic field	50 Hz, 60 Hz 30 A/m	A	IEC 61000-4-8	± 0,7 H_{low}
6	Conducted disturbances: Voltage dips Voltage interruptions	100 % reduction for 1 period (20 ms at 50 Hz) 30 % reduction for 500 ms 60 % reduction for 200 ms 100 % reduction for 5 000 ms	B C C C	IEC 61000-4-11	± 0,7 H_{low}
7	Radio-frequency amplitude modulated electromagnetic field	80 MHz to 2,4 GHz: 30 V/m [d] (rms, unmodulated) 80 % AM (1 kHz) impinging to at least two sides of the device under test and with both polarities of the radio-frequency field	A	IEC 61000-4-3 For badges: test at 30 V/m with a frequency sweep; For all other parts of the dosimetry system containing electronic components such as the reader: test at 30 V/m with at least the frequencies stated below [e]; if that test leads to a failure then test at 10 V/m from all six sides.	± 0,7 H_{low}

[a] A: Device works properly during and after the test;
B: Device works properly after the test;
C: Device may be shut down during the test but it shall be possible to switch it on after the test;
For details, see IEC 61000-6-2.

[b] Only if cables above 3 m are allowed by the manufacturer.

[c] Only if cables above 30 m are allowed by the manufacturer.

[d] 30 V/m is used as with this the number of orientations of the device under test can be reduced.

[e] Frequencies for the Radio-frequency test:
98 / 202 / 434 / 550 / 710 / 873 / 903 / 915 / 947 / 1 472 / 1 800 / 1 890 / 2 035 / 2 150 / 2 450 MHz.

Table 16 – Mechanical disturbances performance requirements for dosemeters

Line	Influence quantity	Mandatory range of influence quantity	Maximum permitted deviation, D, for the rated range at a dose of $H = 7\ H_{low}$	Subclause
1	Drop on surface (dosemeter)	1,0 m onto concrete surface (IEC 60068-2-31)	$\pm$ 0,7 H_{low}	15.2

Table 17 – List of abbreviations

Abbreviation	Meaning
CRC	cyclic redundancy check
DIS	direct ion storage
TLD	thermoluminescence detector
WLAN	wireless local area network

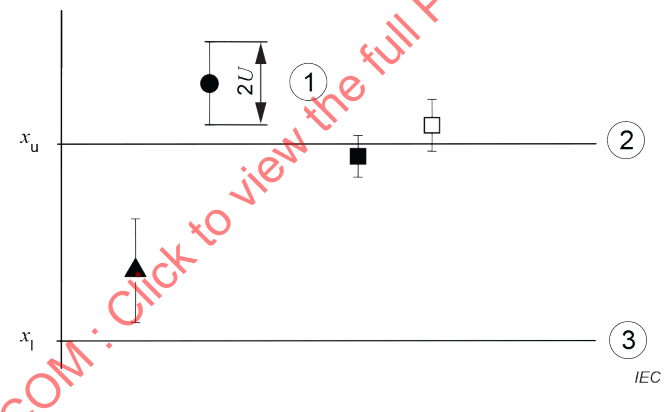
Annex A
(normative)

Confidence limits

A.1 General

If the magnitude of the random uncertainty of an indicated value is a significant fraction of the permitted tolerances of this indicated value, the random uncertainty shall be considered by performing more than one measurement (see 5.2.1). The number of measurements or the sample size shall be chosen in such a way that the confidence interval obtained for each mean, $\bar{x}$, for a confidence level of 95 % (that is the expanded uncertainty of the indicated value, U) lies either within the limits of variation of the indicated value permitted in the test (test passed, triangle in Figure A.1) or outside of these limits (test failed, circle in Figure A.1). If one of the permitted limits of variation, x_u or x_l, lies within the confidence interval (squares in Figure A.1), the number of measurements or the sample size can be increased up to a number of 25 to reduce the width $2 \cdot U$ of the confidence interval, in order to reach one of the two cases mentioned above, which are necessary for an unequivocal decision of passing the test or not.

In case the number of measurements or the sample size is already 24, the test is passed if the mean $\bar{x}$ lies inside the permitted limits of variation (filled square) and the test is failed if the mean $\bar{x}$ lies outside the permitted limits of variation (open square).



Key

1 Confidence interval of the mean, width 2 U

2 Permitted upper limit of variation, x_u

3 Permitted lower limit of variation, x_l

Figure A.1 – Test for confidence interval

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

$$x_l < \bar{x} \pm U < x_u \tag{A.1}$$

If it turns out to be necessary to reduce the width $2 \cdot U$ of the confidence interval, the number of measurements should be increased.

A.2 Confidence interval for the mean, $\bar{x}$

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

$$(\bar{x} - U_{\mathrm{m}},\ \bar{x} + U_{\mathrm{m}}) \tag{A.2}$$

where U_{m} is the half-width of the confidence interval of $\bar{x}$ which is the expanded uncertainty of a mean value. When calculating $\bar{x}$ from n measurements, the half-width of the confidence interval at a confidence level of 95 % is given by (see ISO/IEC Guide 98-3:2008, C.3.2 and G.3, formula G.1d):

$$U_{\mathrm{m}} = \frac{t_{n-1}}{\sqrt{n}} \cdot s \tag{A.3}$$

where s is the standard deviation for the specific group of measurements, and t_{n-1} (coverage factor for the double sided confidence level of 95 %) is taken from Table A.1 for n measurements. For example, for n = 10, $U_{\mathrm{m}} = \frac{2{,}262}{\sqrt{10}} \cdot s = 0{,}72 \cdot s$.

Table A.1 – Student's *t*-value for a double sided 95 % confidence interval

n	t_{n-1}	$\frac{t_{n-1}}{\sqrt{n}}$
2	12,71	8,98
3	4,30	2,48
4	3,18	1,59
5	2,78	1,24
6	2,57	1,05
7	2,45	0,925
8	2,36	0,836
9	2,31	0,769
10	2,26	0,715

n	t_{n-1}	$\frac{t_{n-1}}{\sqrt{n}}$
15	2,14	0,554
20	2,09	0,468
24	2,06	0,410
25	2,06	0,413
30	2,05	0,373
40	2,02	0,320
60	2,00	0,258
120	1,98	0,181
∞	1,96	$1{,}96/\sqrt{n}$

A.3 Confidence interval for a combined quantity

Suppose the mean values of w quantities $\bar{x}_i$ (i = 1..w) and the half-widths of the corresponding confidence intervals U_i (i = 1..w) to be given; the U_i are calculated according to formula (A.3). Let $\bar{x}$ be a combined quantity from these w mean values:

$$\bar{x} = f(\bar{x}_1, \bar{x}_2, .., \bar{x}_w) \tag{A.4}$$

Then the half-width of the confidence interval U_{com} for the combined quantity $\bar{x}$ represents the expanded uncertainty of $\bar{x}$ and is approximately given by:

$$U_{\mathrm{com}} \approx \sqrt{\sum_{i=1}^{w} \left(\frac{\partial \bar{x}}{\partial x_i} \cdot U_i \right)^2} \tag{A.5}$$

This is only valid, if the w quantities are normally distributed (see ISO/IEC Guide 98-3:2008, E.3.3) and not correlated. The correct way to determine the confidence interval for the combined quantity $\bar{x}$ is described in the ISO/IEC Guide 98-3:2008, G.4.1. Nevertheless, for the purpose of this document, formula (A.5) can be used as a good approximation. The following examples use formula (A.5).

EXAMPLE 1 $\bar{x} = \bar{x}_1 \pm \bar{x}_2$ hence $U_{\text{com}} \approx \sqrt{U_1^2 + U_2^2}$

in general $\bar{x} = \sum_{i=1}^{n} \bar{x}_i$ hence $U_{\text{com}} \approx \sqrt{\sum_{i=1}^{n} U_i^2}$

EXAMPLE 2 $\bar{x} = \dfrac{\bar{G}_1}{\bar{G}_{\text{r},0}}$ hence $U_{\text{com}} \approx \dfrac{\bar{G}_1}{\bar{G}_{\text{r},0}} \cdot \sqrt{\left(\dfrac{U_1}{\bar{G}_1}\right)^2 + \left(\dfrac{U_{\text{r},0}}{\bar{G}_{\text{r},0}}\right)^2}$

NOTE 1 U_1 and $U_{\text{r},0}$ are calculated according to formula (A.3).

Suppose group 1 of n = 10 dosemeters was irradiated to a conventional quantity value of C_1 = 0,1 mSv. The reference group of n = 5 dosemeters was irradiated to $C_{\text{r},0}$ = 3 mSv.

The indicated values for the two groups are, for group 1:

0,094 mSv; 0,097 mSv; 0,086 mSv; 0,091 mSv; 0,092 mSv;
0,103 mSv; 0,093 mSv; 0,087 mSv; 0,087 mSv; 0,094 mSv.

and for the reference group:

2,82 mSv; 2,97 mSv; 3,04 mSv; 2,96 mSv; and 2,96 mSv.

From the above values, $\bar{G}_1 = 0{,}0924$, $\bar{G}_{\text{r},0} = 2{,}950$, s_1 = 0,00517 and $s_{\text{r},0}$ = 0,0800 are calculated. Using formula (A.3) leads to U_1 = 0,00370 and $U_{\text{r},0}$ = 0,0993. For the quotient $\dfrac{\bar{G}_1}{\bar{G}_{\text{r},0}} = 0{,}0313$, it results $U_{\text{com}} \approx 0{,}00164$. Thus, the term $\left(\dfrac{\bar{G}_1}{\bar{G}_{\text{r},0}} \pm U_{\text{com}}\right) \cdot \dfrac{C_{\text{r},0}}{C_1}$ results in 0,940 ± 0,049 representing the confidence interval of the relative response at a confidence level of 95 %: 0,89 to 0,99.

NOTE 2 The response values are R_1 = 0,924 and $R_{\text{r},0}$ = 0,983 leading to a relative response of r = 0,940.

Assume, that the relative response is allowed to be between 0,91 and 1,11. Assuming the expanded uncertainties of the conventional quantity values C_1 and $C_{\text{r},0}$ to be $U_{C,\text{rel; r},0}$ = 2,5 % and $U_{C,\text{rel; }1}$ = 2,5 %, respectively, leads to $U_{C,\text{com}} = \sqrt{U_{C,\text{rel;r},0}^2 + U_{C,\text{rel;}1}^2} = 0{,}035$. This leads to the following allowed limits: 0,87 to 1,15.

In conclusion, the inequation $0{,}91 - U_{C,\text{com}} \le \left(\dfrac{\bar{G}_i}{\bar{G}_{\text{r},0}} \pm U_{\text{com}}\right) \cdot \dfrac{C_{\text{r},0}}{C_i} \le 1{,}11 + U_{C,\text{com}}$ becomes

0,87 ≤ 0,89.. 0,99 ≤ 1,15 and is fulfilled. This test is passed.

Annex B
(informative)

Causal connection between readout signals, indicated value and measured value

The causal connection between (readout) signal(s) (see 3.40), indicated value (see 3.14) and the measured value (see 3.22) is shown in the following Figure B.1.

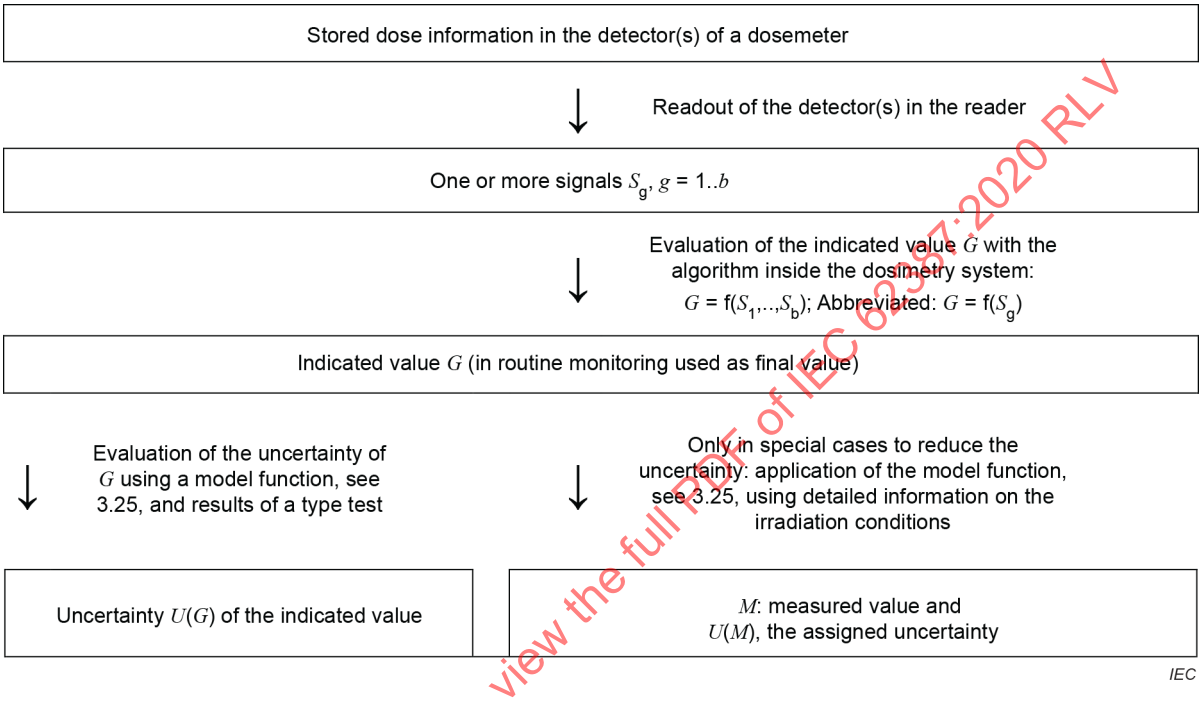


Figure B.1 – Data evaluation in dosimetry systems

The starting point of data evaluation is the stored dose information in the detector(s).

This information is read out and the reader generates one or more signals, for example the charge measured in a photomultiplier tube due to TL-light, called S_1: b = 1. In the case $b > 1$, this indicates that more than one signal can be present from one dosemeter.

Using this signal as a basis, the dosimetry system (computer or whatever) evaluates the value that will be indicated. To determine this indicated value G from the signal(s), a number of steps are automatically done inside the dosimetry system. Examples for these steps are the application of corrections for the detector sensitivity and reader calibration and the application of a computer algorithm for combining more than one signal. These steps are summarized in the function $f(S_g)$ (see 8.6). In routine monitoring, the indicated value G is used as the final result. In other words: the instrument constant, c_i, is unity, see 3.18. However, the uncertainty of G is not known up to this point.

The uncertainty $U(G)$ of the indicated value can be determined using a model function (see 3.25) and further information, for example results of a type test according to this document.

In case a very precise dose value shall be determined, for example in an accidental situation, detailed information on the irradiation conditions can be used to correct the indicated value. This can be done using a model function (see 3.25). The result is called measured value M because it is quite close to the traditionally called true dose value with a small uncertainty.

The two latter steps are explained in detail in IEC TR 62461.

Annex C
(informative)

Overview of the necessary actions that have to be performed for a type test according to this document

In Table C.1 a schedule for a type test for a dosemeter, that fulfils this document for the mandatory ranges, is given. Extending the rated ranges means that more irradiations have to be performed.

Table C.1 – Schedule for a type test of a dosemeter for $H_p(10)$ fulfilling the requirements within the mandatory ranges

Line	Characteristic under test	Action to be taken for the type test	Number of groups / dosemeters to be irradiated	Clause/ Sub-clause
1	Capability of the dosimetry system	Documentation of the manufacturer: check whether the mandatory ranges are covered	0 / 0	7
2	Requirements to the design of the dosimetry system	Documentation of the manufacturer: check whether the requirements are fulfilled and the evaluation algorithm is given	0 / 0	8
3	Effects of radiation not intended to be measured	Documentation of the manufacturer: check whether the response to neutron radiation is given	0 / 0	8.7
4	Instruction manual	Check the manual	0 / 0	9
5	Software, data and interfaces	Check the documentation of the manufacturer and perform simple tests	0 / 0	10
6	Relative response due to non-linearity	Perform irradiations	9 / 72	11.3
7	Coefficient of variation, v			11.2
8	Overload, after-effects, and reusability	Perform irradiations	4 / 26	11.4
9	Relative response due to mean photon radiation energy and angle of incidence	Check whether the construction of the dosemeter is symmetrical with respect to rotation, then perform irradiations	Sym. Constr.:24 / 96 Non-sym.: 48 / 192	11.5.1
10	Relative response due to mean beta radiation energy	Perform irradiations	1 / 5	11.5.2
11	As in line 9 and 10 but new reference direction opposite to that one used	Check whether the information is given on the dosemeter or whether the dosemeter is symmetrical with respect to detector plane; if both is not the case, perform irradiations	Mostly 0 / 0 Maybe as line 9	8.4 f)
12	Radiation incidence from the side of the dosemeter	Check by looking at the construction of the dosemeter: side walls thicker than front? If not, perform irradiations	Mostly 0 / 0 Maybe 6 / 24	11.8
13	Response to mixed irradiations	Check by understanding the evaluation algorithm; if it is not additive, use irradiations from Clause 11 and perform calculations according to Clause 12 and Annex F	Mostly 0 / 0 Maybe 3 / 12	12
14	Relative response due to environmental performance requirements	Perform irradiations and additional influences, for example storing of three groups for a time of t_{max}	21/126	13
15	Deviation due to electromagnetic performance requirements	Perform irradiations and additional influences	8 / 130	14
16	Deviation due to mechanical performance requirements	Perform irradiations and additional influences	4 / 24	15

Annex D
(informative)

Uncertainty of dosimetry systems

It is advisable that the dosimetry system is in line with the recommendations on accuracy stated in paragraph 251 of ICRP 75:1997. That means, the response of the dosimetry systems in routine use shall lie within a factor of 1,5 in either direction for photon radiation at a 95 % (k = 2) confidence level. This is the case if the dosemeter is worn correctly at the representative part of the body, if all influence quantities are within their rated ranges, and if the standard uncertainty determined according to IEC TR 62461 is less than or equal to 17 % (k = 1).

Annex E
(informative)

Conversion coefficients $h_{pD}(0,07;source;\alpha)$, $h'_D(0,07;source;\alpha)$, $h_{pD}(3;source;\alpha)$, and $h'_D(3;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the corresponding dose equivalent quantities for radiation qualities defined in ISO 6980-1

In Tables E.1 to E.5 conversion coefficients from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the different dose equivalent quantites are given for radiation qualities defined in ISO 6980-1. The values were obtained by measurements with a beta primary standard for absorbed dose to tissue (embedded in a slab phantom), see Behrens and Buchholz (2011). Corrections to account for the difference from the slab (used to determine $D_p(0,07)$) to other phantoms (to be used during calibration and irradiation of dosemeters) and to the ICRU sphere were taken into account, see Behrens (2015). The standard uncertainties (k = 1) are stated in the tables.

The values given in the following tables shall only be used as long as such values are not included in ISO 6980-3 or in any other documents or scientific publications.

Table E.1 – Conversion coefficients $h_{pD}(0,07;source;\alpha)_{slab}$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(0,07)$ for the slab phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(0,07;source;\alpha)_{slab}$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
^{147}Pm	no	11	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{147}Pm	yes	20	1,000 ± 0,000	0,960 ± 0,002	0,870 ± 0,007	0,720 ± 0,013	0,530 ± 0,016	n.a.
^{85}Kr	yes	30	1,000 ± 0,000	0,990 ± 0,001	0,960 ± 0,005	0,880 ± 0,010	0,720 ± 0,014	0,490 ± 0,015
^{85}Kr	yes	50	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	11	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	20	1,000 ± 0,000	1,020 ± 0,001	1,060 ± 0,006	1,140 ± 0,013	1,210 ± 0,024	n.a.
^{90}Sr/^{90}Y	no	30	1,000 ± 0,000	1,010 ± 0,001	1,060 ± 0,006	1,130 ± 0,013	1,160 ± 0,023	0,910 ± 0,027
^{90}Sr/^{90}Y	no	50	1,000 ± 0,000	1,010 ± 0,001	1,050 ± 0,006	1,100 ± 0,013	1,100 ± 0,022	0,840 ± 0,025
^{90}Sr/^{90}Y	yes	30	1,000 ± 0,000	1,010 ± 0,001	1,060 ± 0,006	1,120 ± 0,013	1,140 ± 0,023	0,860 ± 0,025
^{90}Sr/^{90}Y	yes	50	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	11	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	20	1,000 ± 0,000	1,011 ± 0,001	1,06 ± 0,006	1,151 ± 0,013	1,256 ± 0,025	n.a.
^{106}Ru/^{106}Rh	yes	30	1,000 ± 0,000	0,998 ± 0,001	1,039 ± 0,006	1,127 ± 0,013	1,195 ± 0,024	1,003 ± 0,030
^{106}Ru/^{106}Rh	yes	50	1,000 ± 0,000	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.2 – Conversion coefficients $h_{pD}(0,07;source;\alpha)_{rod}$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(0,07)$ for the rod phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(0,07;source;\alpha)_{rod}$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
^{147}Pm	no	11	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{147}Pm	yes	20	1,000 ± 0,005	0,960 ± 0,005	0,870 ± 0,008	0,720 ± 0,013	0,534 ± 0,016	n.a.
^{85}Kr	yes	30	1,000 ± 0,005	0,990 ± 0,005	0,960 ± 0,007	0,880 ± 0,013	0,728 ± 0,016	0,506 ± 0,015
^{85}Kr	yes	50	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	11	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	20	0,987 ± 0,005	1,006 ± 0,005	1,042 ± 0,008	1,122 ± 0,014	1,227 ± 0,025	n.a.
^{90}Sr/^{90}Y	no	30	0,987 ± 0,005	0,996 ± 0,005	1,042 ± 0,008	1,112 ± 0,014	1,176 ± 0,024	1,052 ± 0,032
^{90}Sr/^{90}Y	no	50	0,987 ± 0,005	0,996 ± 0,005	1,032 ± 0,008	1,082 ± 0,014	1,115 ± 0,023	0,971 ± 0,029
^{90}Sr/^{90}Y	yes	30	0,987 ± 0,005	0,996 ± 0,005	1,042 ± 0,008	1,102 ± 0,014	1,156 ± 0,024	0,994 ± 0,030
^{90}Sr/^{90}Y	yes	50	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	11	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	20	0,987 ± 0,005	0,993 ± 0,006	1,037 ± 0,008	1,120 ± 0,014	1,251 ± 0,026	n.a.
^{106}Ru/^{106}Rh	yes	30	0,987 ± 0,005	0,980 ± 0,006	1,016 ± 0,008	1,097 ± 0,014	1,190 ± 0,025	1,156 ± 0,035
^{106}Ru/^{106}Rh	yes	50	0,987 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.3 – Conversion coefficients $h'_D(0,07;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H'(0,07)$ for the ICRU sphere for radiation qualities defined in ISO 6980-1

Source			$H'_D(0,07;source;\alpha)$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
^{147}Pm	no	11	1,000 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.
^{147}Pm	yes	20	1,000 ± 0,006	0,960 ± 0,007	0,870 ± 0,012	0,720 ± 0,014	0,530 ± 0,016	n.a.
^{85}Kr	yes	30	1,000 ± 0,006	0,990 ± 0,007	0,96 ± 0,009	0,88 ± 0,013	0,720 ± 0,019	0,490 ± 0,016
^{85}Kr	yes	50	1,000 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	11	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{90}Sr/^{90}Y	no	20	1,000 ± 0,005	1,020 ± 0,005	1,060 ± 0,008	1,140 ± 0,016	1,210 ± 0,025	n.a.
^{90}Sr/^{90}Y	no	30	1,000 ± 0,005	1,010 ± 0,005	1,060 ± 0,008	1,130 ± 0,015	1,160 ± 0,024	0,910 ± 0,028
^{90}Sr/^{90}Y	no	50	1,000 ± 0,005	1,010 ± 0,005	1,050 ± 0,008	1,100 ± 0,015	1,100 ± 0,023	0,840 ± 0,026
^{90}Sr/^{90}Y	yes	30	1,000 ± 0,005	1,010 ± 0,005	1,060 ± 0,008	1,120 ± 0,015	1,140 ± 0,024	0,860 ± 0,027
^{90}Sr/^{90}Y	yes	50	1,000 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	11	1,000 ± 0,007	n.a.	n.a.	n.a.	n.a.	n.a.
^{106}Ru/^{106}Rh	no	20	1,000 ± 0,007	1,011 ± 0,008	1,060 ± 0,010	1,151 ± 0,016	1,256 ± 0,026	n.a.
^{106}Ru/^{106}Rh	yes	30	1,000 ± 0,007	0,998 ± 0,008	1,039 ± 0,010	1,127 ± 0,016	1,195 ± 0,025	1,003 ± 0,031
^{106}Ru/^{106}Rh	yes	50	1,000 ± 0,007	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.4 – Conversion coefficients $h_{pD}(3;source;\alpha)_{cylinder}$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H_p(3)$ for the cylinder phantom for radiation qualities defined in ISO 6980-1

Source			$h_{pD}(3;source;\alpha)_{cylinder}$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
$^{90}Sr/^{90}Y$	no	11	0,501 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	20	0,495 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	30	0,476 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	50	0,440 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	yes	30	0,431 ± 0,004	0,407 ± 0,004	0,321 ± 0,004	0,210 ± 0,004	0,105 ± 0,004	0,037 ± 0,002
$^{90}Sr/^{90}Y$	yes	50	0,384 ± 0,003	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	11	0,760 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	20	0,771 ± 0,006	0,743 ± 0,006	0,659 ± 0,008	0,500 ± 0,010	0,291 ± 0,009	n.a.
$^{106}Ru/^{106}Rh$	yes	30	0,757 ± 0,006	0,716 ± 0,006	0,641 ± 0,007	0,486 ± 0,010	0,284 ± 0,009	0,114 ± 0,005
$^{106}Ru/^{106}Rh$	yes	50	0,715 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.

Table E.5 – Conversion coefficients $h'_D(3;source;\alpha)$ from personal absorbed dose in 0,07 mm depth, $D_p(0,07)$, to the dose equivalent $H'(3)$ for the ICRU sphere for radiation qualities defined in ISO 6980-1

Source			$H'_D(3;source;\alpha)$ for an angle of incidence α of					
Nuclide	Beam flattening filter	Distance cm	0°	15°	30°	45°	60°	75°
$^{90}Sr/^{90}Y$	no	11	0,501 ± 0,005	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	20	0,495 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	30	0,476 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	no	50	0,44 ± 0,004	n.a.	n.a.	n.a.	n.a.	n.a.
$^{90}Sr/^{90}Y$	yes	30	0,431 ± 0,004	0,402 ± 0,004	0,320 ± 0,004	0,208 ± 0,004	0,104 ± 0,004	0,035 ± 0,002
$^{90}Sr/^{90}Y$	yes	50	0,384 ± 0,003	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	11	0,760 ± 0,007	n.a.	n.a.	n.a.	n.a.	n.a.
$^{106}Ru/^{106}Rh$	no	20	0,771 ± 0,007	0,743 ± 0,006	0,657 ± 0,008	0,496 ± 0,010	0,284 ± 0,009	n.a.
$^{106}Ru/^{106}Rh$	yes	30	0,757 ± 0,007	0,716 ± 0,006	0,639 ± 0,008	0,483 ± 0,010	0,277 ± 0,009	0,107 ± 0,005
$^{106}Ru/^{106}Rh$	yes	50	0,715 ± 0,006	n.a.	n.a.	n.a.	n.a.	n.a.

Annex F
(informative)

Computational method of test for mixed irradiations

In Figure F.1 a flow chart of a program performing the method of test according to 12.2 is shown. The following notations are valid:

N = 1, 2, …, N_{max} is the pointer to the table entry containing the signals (element responses) S_g(K) for the radiation quality K (g = 1,.b). For example, N = 2 corresponds to "N-20; 15° up".

j = 1, 2, …, (N_{max} – N) is the offset from N to point to the table entry containing the signals (element responses) S_g(L) for the radiation quality L (g = 1,.b). For example, for N = 2 and j = 3 corresponds to row 2+3 = 5: "N-20; 15° right".

i is the weight index from 1 to 9, equivalent to 10 % to 90 % for the dose values C_K and 90 % to 10 % for C_L, respectively. For the above given example, i = 2 corresponds to 20 % dose of "N-20; 15° up" and 80 % dose of "N-20; 15° right".

An example of a dosemeter signal table is given in Table F.1.

Table F.1 – Example of dosemeter response table and range limits

N	Radiation Quality	r_{min}	r_{max}	S_1	S_2	…	S_b
1	N-20; 0°	0,67	2,00	0,80	1,20	…	3,50
2	N-20; 15° up	0,67	2,00	0,72	1,08	…	3,15
3	N-20; 15° down	0,67	2,00	0,70	1,05	…	3,10
4	N-20; 15° left	0,67	2,00	0,63	0,95	…	2,79
5	N-20; 15° right	0,67	2,00	0,65	0,99	…	2,85
6	N-20; 30° up	0,67	2,00	0,70	1,03	…	3,10
…	…	0,67	2,00	…	…	…	…
	N-30; 0°	0,69	1,82	…	…	…	…
	N-30; 15° up	0,69	1,82	…	…	…	…
	…	0,69	1,82	…	…	…	…
	N-80; 0°	0,71	1,67	…	…	…	…
	N-80; 15° up	0,71	1,67	…	…	…	…
	…	0,71	1,67	…	…	…	…
	S-Co; 0°	0,71	1,67	…	…	…	…
	S-Co; 15° up	0,71	1,67	…	…	…	…
	…	0,71	1,67	…	…	…	…
	^{90}Sr/^{90}Y; 0°	0,67	2,00	…	…	…	…
	^{90}Sr/^{90}Y; 15° up	0,67	2,00	…	…	…	…
N_{max}	…	0,67	2,00	…	…	…	…

The required range of response weighted with i and (10 – i) is calculated from the ranges of response for the radiation qualities K and L, $r_{min,K}$ .. $r_{max,K}$ and $r_{min,L}$ .. $r_{max,L}$, by $r_{min,w} = \frac{r_{min,K} \cdot i + r_{min,L} \cdot (10 - i)}{10}$ and $r_{max,w} = \frac{r_{max,K} \cdot i + r_{max,L} \cdot (10 - i)}{10}$.

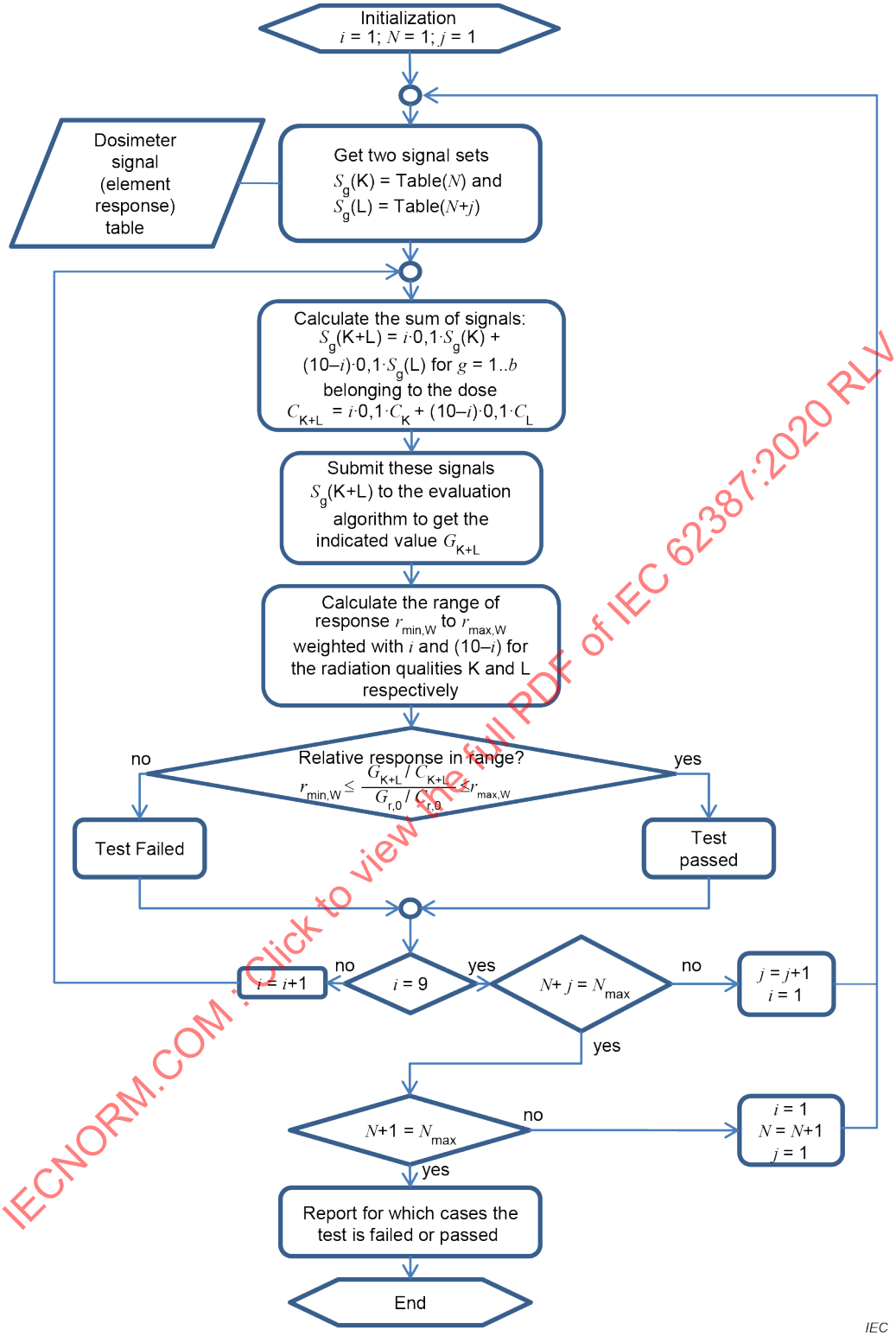


Figure F.1 – Flow chart of a computer program to perform tests according to 12.2

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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INSTRUMENTATION POUR LA RADIOPROTECTION – SYSTÈMES DOSIMÉTRIQUES AVEC DÉTECTEURS INTÉGRÉS PASSIFS POUR LE CONTRÔLE RADIOLOGIQUE INDIVIDUEL, DU LIEU DE TRAVAIL ET DE L'ENVIRONNEMENT DES RAYONNEMENTS PHOTONIQUES ET BÊTA

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La présente deuxième édition annule et remplace la première édition de l'IEC 62387 parue en 2012. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- Modification du titre.

- Ajout d'exigences de performance pour que les dosimètres mesurent $H'(3)$ pour les rayonnements photoniques et bêta.
- Adoption du fantôme cylindre en lieu et place du fantôme plaque pour la grandeur $H_p(3)$.
- Correction et clarification de plusieurs paragraphes pour obtenir une meilleure applicabilité.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
45B/945/FDIS	45B/954/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

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INTRODUCTION

Un système dosimétrique peut comporter les éléments suivants:

a) un dispositif passif, appelé ici *détecteur* qui, après exposition au rayonnement, mémorise un signal à exploiter pour la mesure d'une ou plusieurs grandeurs du champ de rayonnement incident;

b) un "dosimètre", qui comprend plusieurs moyens d'identification, qui contient un ou plusieurs détecteurs et qui peut contenir des composants électroniques, par exemple, pour la lecture (par exemple, dans un dosimètre à DIS (*direct ion storage*);

c) un "lecteur" utilisé pour lire les informations mémorisées (signal) provenant du détecteur, afin de déterminer la dose de rayonnement;

d) un "ordinateur" comportant le "logiciel" adéquat pour contrôler le lecteur, mémoriser les signaux fournis par le lecteur, calculer, afficher et mémoriser la dose évaluée sous la forme d'un fichier électronique ou d'une copie papier;

e) un "équipement supplémentaire" et un document décrivant les procédures (manuel d'instructions) pour réaliser des opérations associées telles que la suppression des informations de dose mémorisées, le nettoyage des dosimètres, ou les opérations nécessaires pour garantir l'efficacité de l'ensemble du système.

INSTRUMENTATION POUR LA RADIOPROTECTION – SYSTÈMES DOSIMÉTRIQUES AVEC DÉTECTEURS INTÉGRÉS PASSIFS POUR LE CONTRÔLE RADIOLOGIQUE INDIVIDUEL, DU LIEU DE TRAVAIL ET DE L'ENVIRONNEMENT DES RAYONNEMENTS PHOTONIQUES ET BÊTA

1 Domaine d'application

Le présent document s'applique à toutes sortes de systèmes dosimétriques passifs utilisés pour la mesure de:

– l'équivalent de dose individuel $H_p(10)$ (pour le contrôle radiologique individuel du corps entier),

– l'équivalent de dose individuel $H_p(3)$ (pour le contrôle radiologique individuel des cristallins),

– l'équivalent de dose individuel $H_p(0,07)$ (pour le contrôle radiologique individuel de la peau du corps entier et de la peau locale et des extrémités),

– l'équivalent de dose ambiant $H^*(10)$ (pour le contrôle radiologique du lieu de travail et de l'environnement),

– l'équivalent de dose directionnel $H'(3)$ (pour le contrôle radiologique du lieu de travail et de l'environnement), ou

– l'équivalent de dose directionnel $H'(0,07)$ (pour le contrôle radiologique du lieu de travail et de l'environnement).

Le présent document s'applique aux systèmes dosimétriques qui mesurent les rayonnements photoniques et/ou bêta externes dans la plage de dose comprise entre 0,01 mSv et 10 Sv et dans les plages d'énergie données dans le Tableau 1. Toutes les valeurs d'énergie données sont des valeurs moyennes par rapport à la fluence. Les systèmes dosimétriques utilisent habituellement des dispositifs électroniques pour l'évaluation des données et sont donc souvent commandés par ordinateur.

Tableau 1 – Plages d'énergie obligatoires et maximales couvertes par le présent document

Grandeur mesurée	Plage d'énergie moyenne obligatoire pour le rayonnement photonique	Plage d'énergie moyenne maximale pour l'essai du rayonnement photonique	Plage d'énergie moyenne obligatoire pour le rayonnement bêta [a]	Plage d'énergie moyenne maximale pour l'essai du rayonnement bêta [a]
$H_p(10)$, $H^*(10)$	80 keV à 1,25 MeV [b]	12 keV à 7 MeV	–	–
$H_p(3)$, $H'(3)$	30 keV à 250 keV	8 keV à 7 MeV	0,8 MeV[c]	0,7 MeV[c] à 1,2 MeV
$H_p(0,07)$, $H'(0,07)$	30 keV à 250 keV	8 keV à 1,25 MeV[b]	0,24 MeV à 0,8 MeV	0,07 MeV[d] à 1,2 MeV[e]

a Les sources de rayonnement bêta suivantes sont proposées pour les différentes valeurs d'énergie moyennes: Pour 0,06 MeV: ^{147}Pm; pour 0,8 MeV: ^{90}Sr/^{90}Y; pour 1,2 MeV: ^{106}Ru/^{106}Rh.

b 1,25 MeV est l'énergie moyenne du rayonnement photonique à partir de ^{60}Co.

c Pour le rayonnement bêta, une énergie de 0,7 MeV est exigée pour atteindre les couches du cristallin sensibles au rayonnement sur une profondeur d'environ 3 mm (approximativement 3 mm de tissu de l'ICRU).

d Pour le rayonnement bêta, une énergie de 0,07 MeV est exigée pour traverser la couche cornée de la peau de 0,07 mm (approximativement 0,07 mm de tissu de l'ICRU).

e Les valeurs d'énergie moyenne bêta 0,08 MeV, 0,7 MeV et 1,2 MeV sont presque équivalentes à une valeur E_{max} de 0,225 MeV, 2,27 MeV et 3,54 MeV, respectivement.

NOTE 1 Dans le présent document, "dose" signifie équivalent de dose, sauf indication contraire.

NOTE 2 Pour $H_p(10)$ et $H^*(10)$, aucun rayonnement bêta n'est considéré. Raisons:

a) $H_p(10)$ et $H^*(10)$ sont des estimations prudentes de la dose effective qui n'est pas une grandeur pertinente pour les rayonnements bêta.

b) Les normes ICRU 56, ICRU 57 ou ISO 6980-3 ne spécifient aucun coefficient de conversion.

NOTE 3 Les plages d'énergie maximales sont les limites d'énergie à l'intérieur desquelles il est possible d'effectuer des essais de type selon le présent document.

NOTE 4 Les dosimètres à DIS sont traités dans le présent document étant donné qu'ils sont souvent utilisés sans affichage en ligne, mais avec un lecteur séparé.

Les méthodes d'essai relatives à la conception (Article 8), au manuel d'instructions (Article 9), au logiciel (Article 10), aux influences de l'environnement (Article 13), aux influences électromagnétiques (Article 14), aux influences mécaniques (Article 15) et à la documentation (Article 16) ne dépendent pas du type de rayonnement. Par conséquent, elles peuvent aussi être appliquées à d'autres systèmes dosimétriques, par exemple pour les neutrons, en utilisant le type de rayonnement correspondant lors des essais.

Le présent document est destiné aux systèmes dosimétriques capables d'évaluer des doses dans la grandeur et l'unité (Sv) exigées à partir des signaux de lecture dans chaque grandeur et unité. La seule correction qui peut être appliquée à la dose évaluée (valeur indiquée) est celle qui résulte de la radiation de bruit de fond naturel en utilisant des dosimètres supplémentaires.

NOTE 5 La correction due à la radiation de bruit de fond naturel peut être effectuée avant ou après le calcul de la dose.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 61000-4-2, *Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques*

IEC 61000-4-4, *Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61000-4-5, *Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc*

IEC 61000-4-6, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectriques*

IEC 61000-4-8, *Compatibilité électromagnétique (CEM) – Partie 4-8: Techniques d'essai et de mesure – Essai d'immunité au champ magnétique à la fréquence du réseau*

IEC 61000-4-11, *Compatibilité électromagnétique (CEM) – Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension*

IEC 61000-6-2, *Compatibilité électromagnétique (CEM) – Partie 6-2: Normes génériques – Norme d'immunité pour les environnements industriels*

ISO 4037 (toutes les parties), *Radioprotection – Rayonnements X et gamma de référence pour l'étalonnage des dosimètres et des débitmètres, et pour la détermination de leur réponse en fonction de l'énergie des photons*

ISO 4037-3:2019, *Radioprotection – Rayonnements X et gamma de référence pour l'étalonnage des dosimètres et des débitmètres, et pour la détermination de leur réponse en fonction de l'énergie des photons – Partie 3: Étalonnage des dosimètres de zone et individuels et mesurage de leur réponse en fonction de l'énergie et de l'angle d'incidence*

ISO 6980 (toutes les parties), *Énergie nucléaire – Rayonnement bêta de référence*

ISO 6980-3, *Énergie nucléaire – Rayonnement bêta de référence – Partie 3: Étalonnage des dosimètres individuels et des dosimètres de zone et détermination de leur réponse en fonction de l'énergie et de l'angle d'incidence du rayonnement bêta*

ISO 8529 (toutes les parties), *Rayonnements neutroniques de référence*

ISO/IEC Guide 98-3:2008, *Incertitude de mesure – Partie 3: Guide pour l'expression de l'incertitude de mesure (GUM:1995)*

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

Plusieurs grandeurs avec des indices spécifiques sont explicitées dans le Tableau 6.

3.1
équivalent de dose ambiant
$H^*(d)$
équivalent de dose en un point d'un champ de rayonnement, qui serait produit par le champ unidirectionnel et expansé correspondant dans la sphère de l'ICRU à une profondeur, d, sur le rayon qui fait face à la direction du champ unidirectionnel

Note 1 à l'article: La profondeur recommandée, d, pour la surveillance dosimétrique en termes de $H^*(d)$ est 10 mm et $H^*(d)$ peut alors s'écrire $H^*(10)$.

[SOURCE: IEC 60050-395:2014, 395-05-43 – La Note 1 à l'article correspond à la note 3 de la source]

3.2
coefficient d'étalonnage
N_0
quotient de la valeur conventionnelle d'une grandeur à mesurer et de l'indication corrigée du dosimètre, $G_{r,0}$, normalisé aux conditions de référence

Note 1 à l'article: Le coefficient d'étalonnage pour la qualité de rayonnement de référence U et pour l'angle d'incidence α est équivalent au facteur d'étalonnage multiplié par le coefficient de l'instrument. Il est donné par

$$N_0 = \frac{C_{r,0}}{G_{r,0}} = C_f(U,\alpha)\cdot c_i$$

où

$C_{r,0}$ est la valeur conventionnelle d'une grandeur, voir 3.5
$G_{r,0}$ est l'indication corrigée, voir 3.14
$C_f(U,\alpha)$ est le facteur d'étalonnage pour la qualité de rayonnement U et l'angle d'incidence α, voir 3.3, et
c_i est la constante de l'instrument, voir 3.18.

Concernant la dimension du facteur d'étalonnage et du coefficient d'étalonnage, voir les notes en 3.3 et 3.18.

Note 2 à l'article: L'inverse du coefficient d'étalonnage est la réponse dans les conditions de référence. La valeur du facteur d'étalonnage peut varier selon l'expression quantitative de la grandeur à mesurer. Dans de tels cas, il est admis que le dosimètre a une réponse non constante (ou une indication non linéaire).

[SOURCE: ISO 29661:2012, 3.1.5, modifié – La Note 3 à l'article a été supprimée]

3.3
facteur d'étalonnage
$C_f(U,\alpha)$
facteur par lequel le produit de l'indication corrigée, $G_{r,0}$, et de la constante de l'instrument associé du dosimètre, c_i, est multiplié afin d'obtenir la valeur conventionnelle d'une grandeur à mesurer dans les conditions de référence

Note 1 à l'article: Le facteur d'étalonnage n'a pas de dimension.

[SOURCE: ISO 29661:2012, 3.1.7]

3.4
coefficient de variation
v
rapport de l'écart type s à la moyenne arithmétique $\overline{G}$ pour une série de n valeurs indiquées G_j (valeur indiquée)

$$v = \frac{s}{\overline{G}} = \frac{1}{\overline{G}}\sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(G_j - \overline{G}\right)^2}$$

3.5
valeur conventionnelle d'une grandeur
C
valeur attribuée à une grandeur par un accord pour un usage donné

Note 1 à l'article: La valeur conventionnelle d'une grandeur C est la meilleure estimation de la grandeur à mesurer déterminée par un étalon primaire, un étalon secondaire, ou encore un étalon de travail traçable à un étalon primaire.

[SOURCE: ISO/IEC Guide 99:2007, 2.12]

3.6
correction de non-linéarité
r_{n}
rapport de la réponse R_{n} dans des conditions dans lesquelles seule la valeur de l'équivalent de dose varie, à la réponse de référence R_0

$$r_{\mathrm{n}} = \frac{R_{\mathrm{n}}}{R_0}$$

Note 1 à l'article: Pour un système dosimétrique linéaire, r_{n} est égale à l'unité.

3.7
facteur d'élargissement
k
facteur numérique utilisé comme multiplicateur de l'incertitude type composée pour obtenir l'incertitude élargie

Note 1 à l'article: Un facteur d'élargissement k a sa valeur typiquement comprise entre 2 et 3.

Note 2 à l'article: Dans le cas d'une loi normale, l'utilisation d'un facteur d'élargissement de 2 engendre une incertitude élargie qui définit un intervalle autour du résultat de mesure qui contient approximativement 95 % de la distribution des valeurs qui peuvent être raisonnablement attribuées au mesurande. Pour d'autres lois, le facteur d'élargissement peut être plus grand.

[SOURCE: GUM 2.3.6:1995, modifié – Le symbole k a été ajouté]

3.8
détecteur
détecteur de rayonnement
appareil ou substance permettant de convertir l'énergie du rayonnement ionisant incident en un signal afin de donner une indication et/ou de fournir une mesure; appareil ou substance qui, en présence d'un rayonnement, fournit directement ou indirectement un signal ou toute autre indication permettant de mesurer une ou plusieurs grandeurs liées au rayonnement incident

Note 1 à l'article: Le détecteur exige habituellement un lecteur séparé pour lire le signal. Cela signifie que le détecteur n'est généralement pas capable de fournir un signal sans un processus de lecture externe.

Note 2 à l'article: Un détecteur passif ne nécessite pas une alimentation externe pour recueillir et mémoriser les informations de dose.

Note 3 à l'article: Lire dans l'IEV "détecteur de rayonnement".

[SOURCE: IEC 60050-881:1983, 881-13-01, modifié – Le terme "détecteur" a été ajouté en tant que premier terme préférentiel]

3.9
écart
D
différence entre les valeurs indiquées de la même valeur du mesurande d'un système dosimétrique, lorsqu'une grandeur d'influence prend successivement deux valeurs différentes

$$D = G - G_r$$

où

G valeur indiquée sous l'effet, et

G_r valeur indiquée dans les conditions de référence

Note 1 à l'article: Le terme original de l'IEV 311-07-03 est "variation (due à une grandeur d'influence)". Afin de ne pas confondre la variation (de la valeur indiquée) et la variation de la réponse, dans la présente norme ce terme est appelé "écart".

Note 2 à l'article: L'écart peut être positif ou négatif selon qu'il entraîne respectivement une augmentation ou une diminution de la valeur indiquée.

[SOURCE: IEC 60050-300-311:2001, 311-07-03, modifié – "écart" a remplacé "variation (due à une grandeur d'influence)" et "système dosimétrique" a remplacé "un appareil de mesure indicateur ou entre les valeurs d'une mesure matérialisée" et les Notes 1 et 2 à l'article ont été ajoutées]

3.10
équivalent de dose directionnel
$H'(d)$
en un point d'un champ de rayonnement, équivalent de dose qui serait produit par le champ expansé correspondant, dans la sphère de l'ICRU à une profondeur, d, sur le rayon de direction spécifiée

Note 1 à l'article: La profondeur actuellement recommandée, d, pour le contrôle radiologique de l'environnement par rapport à la peau locale et au cristallin de l'œil est de 0,07 mm et 3 mm, respectivement, et $H'(d)$ peut alors s'écrire $H'(0{,}07)$ et $H'(3)$, respectivement.

[SOURCE: ICRU 51:1993, modifié – La Note 1 à l'article a été ajoutée]

3.11
dosimètre
radiamètre destiné à la mesure de grandeurs telles que la dose absorbée ou l'équivalent de dose

Note 1 à l'article: Dans un sens plus large, ce terme est utilisé pour les appareils destinés à la mesure d'autres grandeurs relatives aux rayonnements, telles que l'exposition, la fluence, etc. Un tel emploi est déconseillé.

Note 2 à l'article: Cet appareil peut nécessiter l'utilisation d'un lecteur séparé pour lire la dose absorbée ou l'équivalent de dose.

Note 3 à l'article: Un dosimètre est composé habituellement d'un détecteur et d'un badge, par exemple les détecteurs à thermoluminescence (TLD – *thermoluminescence detector*) avec des filtres.

Note 4 à l'article: Un dosimètre peut contenir des composants électroniques (par exemple pour la lecture (par exemple, dans un dosimètre à DIS).

[SOURCE: IEC 60050-395:2014, 395-05-02, modifié – Les Notes 3 et 4 à l'article ont été ajoutées]

3.12
système dosimétrique
dosimètre, lecteur et tous les équipements et procédures associés utilisés pour évaluer la valeur indiquée

3.13
incertitude élargie
U
grandeur définissant un intervalle, autour du résultat d'un mesurage, dont on puisse s'attendre à ce qu'il comprenne une fraction élevée de la distribution des valeurs qui pourraient être attribuées raisonnablement au mesurande

Note 1 à l'article: L'incertitude élargie est obtenue en multipliant l'incertitude type composée par un facteur d'élargissement.

Note 2 à l'article: Un niveau de confiance de 95 % est recommandé pour l'utilisation du présent document.

[SOURCE: GUM:1995, 2.3.5]

3.14
valeur indiquée
indication
G
valeur du mesurande donnée directement par un appareil de mesure sur la base de sa courbe d'étalonnage

Note 1 à l'article: Dans la présente norme, la valeur indiquée est celle donnée en unités d'équivalent de dose (Sv) par les systèmes dosimétriques comme résultat final de l'algorithme d'évaluation (par exemple, l'affichage du logiciel, l'impression), voir 8.2.

Note 2 à l'article: Pour des informations détaillées, voir l'Annexe B.

[SOURCE: IEC 60050-300-311:2001, 311-01-08, modifié – La note originale a été remplacée par les nouvelles Notes 1, 2 et 3 à l'article]

3.15
grandeur d'influence
grandeur qui n'est pas le mesurande, mais qui a un effet sur le résultat du mesurage

Note 1 à l'article: Par exemple, la température d'un instrument de mesure.

Note 2 à l'article: Si l'effet d'une grandeur d'influence sur le résultat d'un mesurage dépend d'une autre grandeur d'influence, ces grandeurs d'influence sont traitées comme une grandeur d'influence unique. Dans la présente norme, il s'agit de deux couples de grandeurs d'influence:

a) énergie du rayonnement et angle d'incidence,

b) température ambiante et humidité relative.

[SOURCE: GUM:1995, B.2.10, modifié – Les Exemples 1, 2 et 3 ont été supprimés et les Notes 1 et 2 à l'article ont été ajoutées]

3.16
grandeur d'influence de type F
grandeur d'influence dont l'effet sur la valeur indiquée induit une modification de la réponse

Note 1 à l'article: L'énergie du rayonnement et l'angle d'incidence du rayonnement en sont des exemples.

Note 2 à l'article: F représente le facteur. L'indication due au rayonnement est multipliée par un facteur dû à la grandeur d'influence.

3.17
grandeur d'influence de type S
grandeur d'influence dont l'effet sur la valeur indiquée est un écart indépendant de la valeur indiquée

Note 1 à l'article: La perturbation électromagnétique en est un exemple.

Note 2 à l'article: Toutes les exigences concernant les grandeurs d'influence de type S sont exprimées en fonction de la valeur de l'écart *D*.

Note 3 à l'article: S représente la somme. L'indication est la somme de l'indication due au rayonnement et de celle due à la perturbation.

3.18
constante de l'instrument
c_i
constante par laquelle l'indication du dosimètre G ou – en cas de corrections ou de normalisation – l'indication corrigée $G_{r,0}$ est multipliée afin de la convertir en la même unité que le mesurande

Note 1 à l'article: Adaptée du rapport ICRU 76.

Note 2 à l'article: Si l'indication de l'instrument est déjà exprimée dans la même unité que le mesurande, la constante de l'instrument, c_i, est inutile. Tel est le cas dans la présente norme.

[SOURCE: ISO 29661:2012, 3.1.17]

3.19
limite inférieure de l'étendue de mesure
H_{min}
plus basse valeur de la dose incluse dans l'étendue de mesure

Note 1 à l'article: H_{low} est équivalent à H_0 dans l'ISO 14146:2018.

3.20
plage obligatoire
plage obligatoire d'utilisation
plus petite plage spécifiée d'une grandeur d'influence ou d'un paramètre d'instrument dans laquelle le système dosimétrique doit fonctionner pour être conforme au présent document

Note 1 à l'article: La seconde colonne du Tableau 8 au Tableau 16 donne les plages obligatoires des grandeurs d'influence traitées dans le présent document.

3.21
temps de mesure maximal assigné
t_{max}
durée continue la plus longue pendant laquelle la dose est accumulée et pendant laquelle toutes les exigences du présent document sont remplies

Note 1 à l'article: Le temps de mesure maximal assigné dépend de la limite inférieure de l'étendue de mesure H_{min}, de l'effacement et d'autres influences.

Note 2 à l'article: Le début de cette durée peut par exemple être l'effacement de la dose par chauffage (pour les TLD) ou une remise à zéro de la dose par logiciel (pour les DIS).

3.22
valeur mesurée
M
valeur qui peut être obtenue à partir de la valeur indiquée G en appliquant la fonction modèle du mesurage

Note 1 à l'article: Pour la fonction "modèle", voir 3.25.

Note 2 à l'article: Pour des informations détaillées, voir l'Annexe B.

3.23
étendue de mesure
plage définie par deux valeurs du mesurande, ou grandeur à fournir, dans laquelle les limites d'incertitude de l'appareil de mesure sont spécifiées

Note 1 à l'article: Dans la présente norme, l'étendue de mesure est la plage d'équivalent de dose pour laquelle les exigences de la présente norme sont satisfaites et, par conséquent, l'incertitude limitée.

[SOURCE: IEC 60050-300-311:2001, 311-03-12, modifié – La note originale a été remplacée par une nouvelle Note 1 à l'article]

3.24
équivalent de dose individuel
$H_p(d)$
équivalent de dose dans le tissu mou, à une profondeur appropriée, d, au-dessous d'un point spécifié du corps

Note 1 à l'article: Les profondeurs recommandées sont 10 mm pour les rayonnements fortement pénétrants, 3 mm pour le contrôle radiologique de la dose dans un cristallin et 0,07 mm pour le contrôle de la dose sur la peau.

Note 2 à l'article: Tissu mou signifie élément de tissu ICRU 4, voir le Rapport ICRU 39.

[SOURCE: ICRU 51:1993, modifié – Les Notes 1 et 2 à l'article ont été ajoutées]

3.25
fonction modèle
modèle mathématique du mesurage qui transforme l'observation ou l'ensemble des observations en résultat de mesure

Note 1 à l'article: La fonction modèle combine la valeur indiquée G avec le coefficient d'étalonnage de référence N_0, la correction de non-linéarité r_n, les l écarts D_p (p = 1..l) pour les grandeurs d'influence de type S et les m valeurs de réponse relative r_q (q = 1..m) pour les grandeurs d'influence de type F. Un exemple de fonction modèle est

$$M = \frac{N_0}{r_n \prod_{q=1}^{m} r_q} \left[G - \sum_{p=1}^{l} D_p \right].$$

Une fonction modèle est nécessaire pour évaluer l'incertitude de la valeur mesurée selon le GUM (voir GUM:1995, 3.1.6, 3.4.1 et 4.1).

Note 2 à l'article: Les calculs selon la fonction modèle ne sont généralement pas réalisés, seulement dans le cas où des grandeurs d'influence spécifiques sont bien connues et où une correction appropriée est appliquée.

Note 3 à l'article: Pour des informations détaillées, voir l'Annexe B.

3.26
point de mesure
point du champ de rayonnement auquel la valeur conventionnelle de la grandeur à mesurer est connue

[SOURCE: ISO 29661:2012, 3.1.23, modifié – "à mesurer" a été ajouté]

3.27
préparation
traitement normal des dosimètres ou détecteurs avant une mesure de dose, auquel il est prévu que les dosimètres ou détecteurs soient soumis en utilisation normale

Note 1 à l'article: Par exemple une procédure d'effacement des informations de dose mémorisées, de réinitialisation des informations de dose au moyen d'un logiciel ou de nettoyage.

3.28
plage assignée
plage assignée d'utilisation
plage des valeurs spécifiées qu'une grandeur d'influence peut prendre sans que l'écart ou la variation de la réponse ne soit supérieur aux limites spécifiées

Note 1 à l'article: Dans l'IEC 60050-300-311:2001, 311-07-05, le terme est "domaine nominal d'utilisation". Dans le présent document, le terme "plage assignée" est utilisé pour éviter les termes compliqués comme "la plage d'utilisation d'une grandeur d'influence" et pour avoir des termes plus aisément compréhensibles comme "plage assignée d'une grandeur d'influence".

Note 2 à l'article: Les grandeurs d'influence peuvent être soit de type S, soit de type F.

[SOURCE: IEC 60050-300-311:2001, 311-07-05, modifié – "plage assignée" a remplacé "domaine nominal" et "l'écart ou la variation de la réponse" a remplacé "variation""; les Notes 1 et 2 à l'article ont été ajoutées]

3.29
lecteur
lecteur de dosimètre
instrument qui permet de lire un ou plusieurs détecteurs dans un dosimètre

Note 1 à l'article: Le signal d'un dosimètre passif peut être une quantité de lumière, une quantité de charges, la transparence d'un film, et ainsi de suite. Ainsi, chaque type de dosimètre passif possède un type très différent de lecteur.

Note 2 à l'article: La lecture peut également être effectuée par des composants de lecture automatique du dosimètre, par exemple, des dosimètres à DIS.

3.30
lecture
procédé de mesure de l'information de dose mémorisée d'un détecteur dans un lecteur

Note 1 à l'article: S_i le dosimètre comporte des composants de lecture automatique, par des exemples des dosimètres à DIS, le signal obtenu peut être corrigé pour les influences telles que la température, l'effacement, etc.

3.31
conditions de référence
ensemble de valeurs et/ou de plages de valeurs spécifiées des grandeurs d'influence pour lequel les incertitudes admissibles d'un système dosimétrique sont les plus petites

[SOURCE: IEC 60050-300-311:2001, 311-06-02, modifié – Après "incertitudes", les mots ", ou les limites d'erreur," ont été supprimés et "système dosimétrique" a remplacé "appareil de mesure"]

3.32
direction de référence
direction, dans le système des coordonnées du dosimètre, par rapport à laquelle l'angle de la direction d'incidence du rayonnement est repéré dans des champs de référence

[SOURCE: ISO 29661:2012, 3.1.29]

3.33
orientation de référence
orientation du dosimètre selon laquelle la direction du rayonnement incident coïncide avec la direction de référence du dosimètre

[SOURCE: ISO 29661:2012, 3.1.31]

3.34
point de référence d'un dosimètre
marque(s) physique(s) sur la surface extérieure du dosimètre (éventuellement décrites dans le manuel) utilisée(s) pour positionner celui-ci par rapport au point de mesure; en l'absence de marques sur la surface extérieure du dosimètre, il convient de considérer le centre géométrique comme le point de référence

3.35
réponse de référence
R_0
réponse pour une valeur de référence, $C_{r,0}$, de la grandeur à mesurer dans les conditions de référence

$$R_0 = \frac{G_{r,0}}{C_{r,0}}$$

où $G_{r,0}$ est la valeur indiquée correspondante

Note 1 à l'article: La réponse de référence est l'inverse du coefficient d'étalonnage de référence.

Note 2 à l'article: Les valeurs de référence pour la dose sont données dans le Tableau 7.

3.36
incertitude relative élargie
U_{rel}
incertitude élargie divisée par le résultat de la mesure

3.37
réponse relative
r
rapport de la réponse R sur la réponse de référence R_0

$$r = \frac{R}{R_0}$$

3.38
réponse d'un ensemble de mesure de rayonnement
R
rapport, dans des conditions spécifiées, donné par la relation:

$$R = \frac{G}{C}$$

où

G est la valeur indiquée de la grandeur mesurée par l'équipement ou l'ensemble en essai (système dosimétrique), et

C est la valeur conventionnelle de cette grandeur

Note 1 à l'article: La valeur de la réponse peut varier avec la dose à mesurer. Dans ce cas, le système dosimétrique est dit non linéaire.

[SOURCE: IEC 60050-395:2014, 395-03-72, modifié – Les lettres représentant des grandeurs ont été modifiées, "valeur indiquée de la grandeur" a remplacé "valeur", "(système dosimétrique)" a été ajouté et les notes originales ont été remplacées par une nouvelle Note 1 à l'article]

3.39
résultat de mesure
ensemble de valeurs attribuées à un mesurande, incluant une valeur, l'incertitude correspondante et l'unité du mesurande

Note 1 à l'article: La valeur centrale de l'ensemble de valeurs peut être sélectionnée comme *valeur mesurée M* (voir 3.22) et un paramètre caractérisant la dispersion peut être sélectionné comme étant l'*incertitude* (voir 3.43).

Note 2 à l'article: Le résultat de mesure se rapporte à *la valeur indiquée donnée par l'instrument* G (voir 3.14) et aux valeurs correctives obtenues lors de l'étalonnage et par l'utilisation d'un *modèle* (voir 3.25).

Note 3 à l'article: L'estimation de M peut être basée sur une ou plusieurs valeurs indiquées.

[SOURCE: IEC 60050-300-311: 2001, 311-01-01, modifié – "incluant une valeur, l'incertitude correspondante et l'unité du mesurande" a été ajouté, les Notes 1, 4 et 5 originales ont été supprimées et les termes des Notes 1 et 2 à l'article ont été harmonisés avec les termes utilisés dans le présent document]

3.40
signal
S
grandeur obtenue par un lecteur à partir de la lecture d'un détecteur dont la valeur indiquée de l'équivalent de dose est évaluée

Note 1 à l'article: Par exemple, la charge mesurée dans un tube photomultiplicateur par la lumière émise par un TL; la surface d'une certaine région de la courbe de luminescence d'un TLD; un paramètre de comparaison évalué à partir de l'analyse de la courbe de luminescence.

Note 2 à l'article: En principe, il est possible d'obtenir plus d'un signal à partir d'un même détecteur (par exemple plusieurs paramètres de comparaison à partir de l'analyse de la courbe de luminescence).

Note 3 à l'article: L'utilisation de plus d'un détecteur conduit toujours à l'utilisation de plus d'un signal.

Note 4 à l'article: Dans l'ISO 12794:2000, 3.13, "signal" est assimilé à "valeur de lecture".

Note 5 à l'article: Pour des informations détaillées, voir l'Annexe B.

3.41
écart type
écart type expérimental
s
pour une série de n mesurages du même mesurande, grandeur s caractérisant la dispersion des résultats

$$s = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(G_j - \overline{G}\right)^2}$$

où

G_j est le résultat du j-ème mesurage, et

$\overline{G}$ est la moyenne arithmétique des n résultats considérés

Note 1 à l'article: En considérant la série de n valeurs comme échantillon d'une loi de probabilité $\overline{G}$ est un estimateur sans biais de la moyenne μ, et s^2 est un estimateur sans biais de la variance σ^2 de cette loi.

Note 2 à l'article: L'expression $s/\sqrt{n}$ est une estimation de l'écart type de la loi de $\overline{G}$ et est appelée "écart type expérimental de la moyenne".

Note 3 à l'article: "L'écart type expérimental de la moyenne" est parfois appelé à tort "erreur type de la moyenne".

[SOURCE: GUM:1995, B.2.17, modifié – Le terme préférentiel "écart type" a été ajouté, ainsi que le symbole s, et la formule a été modifiée]

3.42
conditions normales d'essai
conditions représentées par la gamme des valeurs correspondant aux grandeurs d'influence dans lesquelles un étalonnage ou une détermination de la réponse sont mis en œuvre

Note 1 à l'article: Il convient d'apporter les corrections appropriées aux conditions de référence

Note 2 à l'article: Idéalement, il convient d'effectuer les étalonnages dans les conditions de référence. Du fait que cela n'est pas toujours réalisable (par exemple, pour la pression de l'air ambiant) ou pratique (par exemple, pour la température ambiante), un (faible) intervalle autour des valeurs de référence est acceptable. Les valeurs des conditions normales d'essai ainsi que les conditions de référence sont fournies dans le Tableau 7.

Note 3 à l'article: Pendant les essais de type, toutes les valeurs des grandeurs d'influence qui ne sont pas l'objet de l'essai sont fixées dans le domaine des conditions normales d'essai.

[SOURCE: ISO 29661:2012, 3.1.36, modifié – La Note 3 à l'article a été ajoutée]

3.43
incertitude type
u
incertitude du résultat d'un mesurage exprimée sous la forme d'un écart type

Note 1 à l'article: L'incertitude type est un terme plus général que l'écart type. L'incertitude type peut contenir également par exemple des contributions à l'incertitude évaluées en utilisant des méthodes non statistiques.

[SOURCE: GUM:1995, 2.3.1, modifié – La Note 1 à l'article a été ajoutée, ainsi que le symbole u]

3.44
essai de type
essai de conformité effectué sur une ou plusieurs entités représentatives de la production

[SOURCE: IEC 60050-151:2001, 151-16-16]

3.45
limite supérieure de l'étendue de mesure
H_{max}
valeur de la dose la plus élevée incluse dans l'étendue de mesure

3.46
contrôle radiologique de zone
contrôle radiologique d'un lieu de travail ou d'une zone de l'environnement par mesurages de (débit de) dose

Note 1 à l'article: Le contrôle radiologique de zone est effectué pour $H'(0,07)$, $H'(3)$ ou $H^*(10)$.

Note 2 à l'article: Définition orientée CIPR 103 et CIPR 116.

3.47
contrôle radiologique du lieu de travail
contrôle radiologique de zone par mesurages de (débit de) dose effectués dans l'environnement de travail

Note 1 à l'article: Généralement opposé au contrôle radiologique individuel.

Note 2 à l'article: Le contrôle radiologique du lieu de travail est effectué pour $H'(0,07)$, $H'(3)$ ou $H^*(10)$.

3.48
contrôle radiologique de l'environnement
contrôle radiologique de zone par mesurage de (débit de) dose externe effectué dans l'environnement

Note 1 à l'article: Le contrôle radiologique de l'environnement est effectué pour $H'(0,07)$, $H'(3)$ ou $H^*(10)$.

3.49
contrôle radiologique individuel
contrôle radiologique par mesurages de (débit de) dose effectués par l'équipement porté par les travailleurs ou mesurages des quantités de matières radioactives présentes dans leur organisme ou sur leur corps

Note 1 à l'article: Également appelé contrôle radiologique du personnel. Généralement opposé au contrôle radiologique du lieu de travail.

Note 2 à l'article: Le contrôle radiologique individuel est effectué pour $H_p(0,07)$, $H_p(3)$ or $H_p(10)$.

[SOURCE: Glossaire de l'IAEA:2016, modifié – "(débit de) dose" et la Note 2 à l'article ont été ajoutés]

4 Unités et symboles

Dans le présent document, les unités du système international (SI) sont utilisées. Néanmoins, les unités suivantes peuvent être acceptées comme d'usage courant:

– pour l'énergie: l'électronvolt (symbole eV). 1 eV = 1,602 × 10^{-19} J;
– pour le temps: année, mois, jour, heure (symbole h), minute (symbole min).

Les multiples et sous-multiples des unités SI peuvent être utilisés selon le système SI.

L'unité SI d'équivalent de dose est 1 J kg^{-1}.

Le nom spécial de l'unité d'équivalent de dose est le sievert (symbole Sv). 1 Sv = 1 J kg^{-1}.

Une liste des symboles est donnée dans le Tableau 6.

Une liste des abréviations est donnée dans le Tableau 17.

5 Procédures générales d'essai

5.1 Procédures d'essai de base

5.1.1 Consignes d'utilisation

Les consignes d'utilisation des systèmes dosimétriques doivent être données sans aucune ambiguïté dans le manuel, voir l'Article 9. Ces consignes doivent être les mêmes pour toutes les parties de l'essai de type et également pour l'utilisation normale.

5.1.2 Nature des essais

Les essais énumérés dans le présent document sont considérés comme des essais de type, voir l'Annexe C.

5.1.3 Conditions de référence et conditions normales d'essai

Les conditions de référence sont données dans la deuxième colonne du Tableau 7 (à la fin de ce document). Sauf spécification contraire, les essais doivent être effectués dans les conditions normales d'essai données dans la troisième colonne du Tableau 7.

Sauf spécification contraire donnée dans la procédure d'essai, toutes les grandeurs d'influence doivent être maintenues dans les limites établies pour les conditions normales d'essai données dans le Tableau 7, sauf pour les grandeurs d'influence actuellement en essai.

5.1.4 Production du rayonnement de référence

La nature, la construction et les conditions d'utilisation du rayonnement ionisant doivent être conformes aux recommandations des documents suivants:

a) la série ISO 4037 pour le rayonnement photonique,
b) la série ISO 6980 pour le rayonnement bêta, et
c) la série ISO 8529 pour le rayonnement neutronique.

5.1.5 Choix du fantôme à des fins d'essai

Pour les essais impliquant l'utilisation d'un fantôme, les fantômes ISO décrits en 7.3.1 de l'ISO 4037-3:2019 doivent être utilisés. La géométrie d'irradiation exigée est spécifiée dans la norme ISO de référence appropriée (ISO 4037-3 ou ISO 6980-3).

5.1.6 Position du dosimètre à des fins d'essai

Pour les essais impliquant l'utilisation de rayonnement, le point de référence du dosimètre doit être placé au point de mesure, et le dosimètre doit être orienté dans l'orientation de référence. Cela ne s'applique pas aux essais destinés à déterminer la réponse selon l'angle d'incidence.

5.2 Procédures d'essai applicables à tout essai

5.2.1 Nombre de dosimètres utilisés pour chaque essai

Le nombre n de dosimètres (ou d'irradiations) utilisé pour chaque essai peut ne pas être le même pour chaque essai, mais il peut être déterminé en utilisant l'Annexe A. Cependant, il peut être pratique d'utiliser de manière arbitraire 4, 5, 8, 10 ou 20 dosimètres (ou irradiations), nombres pour lesquels la valeur t de Student, donnée dans le Tableau A.1 de l'Annexe A, est égale à 3,18; 2,78; 2,37; 2,26; ou 2,09 respectivement.

NOTE L'utilisation de l'Annexe A démontre que les exigences de performances sont satisfaites avec un intervalle de confiance de 95 %.

5.2.2 Considérations relatives à l'incertitude de la valeur conventionnelle d'une grandeur

L'incertitude relative élargie $U_{C,\mathrm{rel}}$ de la valeur conventionnelle d'une grandeur C de l'équivalent de dose doit être prise en compte. Elle doit être inférieure à 8 % pour un intervalle élargi de 95 %. Le laboratoire d'essai doit déterminer $U_{C,\mathrm{rel}}$ selon le GUM.

NOTE Conformément à 3.13, le niveau de confiance est 95 %.

5.2.3 Considérations relatives à la non-linéarité

L'effet de la non-linéarité dû à la dépendance vis-à-vis de la dose doit être considéré.

Une méthode pratique consiste à commencer les essais par la non-linéarité et à réaliser les autres essais dans une région de dose dans laquelle la non-linéarité est négligeable (1 % à 2 %).

5.2.4 Considérations relatives à la radiation de bruit de fond naturel

Pour le mesurage des équivalents de faible dose ou des débits d'équivalents de faible dose, il est nécessaire de tenir compte de la contribution apportée par la radiation de bruit de fond naturel à l'équivalent de dose. Cette prise en compte s'effectue généralement en utilisant un nombre important de dosimètres (10 au minimum) comme dosimètres de bruit de fond. Ces dosimètres sont traités dans les mêmes conditions que les dosimètres en essai, mais ne sont pas irradiés. La valeur moyenne indiquée de ces dosimètres doit être soustraite de la valeur indiquée par les dosimètres en essai.

5.2.5 Considérations relatives à un dosimètre avec plusieurs détecteurs ou signaux

Si plusieurs signaux (voir 3.40) ou détecteurs (voir 3.8) sont utilisés pour évaluer la valeur indiquée, chaque signal ou détecteur doit être soumis séparément aux essais. Des essais séparés sont nécessaires quand les différents signaux sont utilisés pour évaluer la valeur indiquée dans différentes régions de l'étendue de mesure ou dans différentes régions d'une grandeur d'influence.

NOTE Si cela s'applique, ceci signifie que le nombre total d'essais selon le présent document est multiplié par le nombre de signaux utilisés dans différentes étendues.

EXEMPLE 1 Si un second détecteur ou signal est utilisé pour évaluer un équivalent de dose supérieur à 200 mSv, pour ce détecteur ou signal, toutes les exigences du présent document doivent être mesurées dans sa plage de fonctionnement, c'est-à-dire au-dessus d'un équivalent de dose de 200 mSv.

EXEMPLE 2 Si un second détecteur ou signal est utilisé pour évaluer la dose pour des particules de très faible énergie (par exemple un détecteur très fin pour les rayonnements bêta de faible énergie), pour ce détecteur ou signal, toutes les exigences du présent document doivent être mesurées dans sa plage de fonctionnement, c'est-à-dire les particules de faible énergie.

5.2.6 Réalisation optimale des essais

Pour les essais concernant l'effet de plusieurs grandeurs d'influence, différents groupes de dosimètres sont irradiés: un groupe de référence et un ou plusieurs groupes d'essai pour lesquels l'effet de la grandeur d'influence est mesuré. Pour limiter le nombre d'irradiations nécessaires, il est approprié de combiner les essais de 11.9 à l'Article 15 avec seulement deux ou trois groupes de référence.

Une liste d'actions nécessaires pour réaliser un essai de type selon le présent document est donnée à l'Annexe C.

6 Exigences de performances: synthèse

Pour les types de dosimètres suivants, les grandeurs suivantes doivent au moins être mesurées:

– dosimètres individuels du corps entier:	$H_p(10)$ dû au rayonnement photonique,
– dosimètres individuels de cristallin utilisés dans des champs de rayonnement purement photonique:	$H_p(0,07)$ ou $H_p(3)$ dû au rayonnement photonique,
– dosimètres individuels de cristallin utilisés dans des champs de rayonnement bêta et/ou des champs mixtes de rayonnements bêta et photonique:	$H_p(3)$ dû aux rayonnements bêta et photonique,
– dosimètres individuels d'extrémités:	$H_p(0,07)$ dû aux rayonnements photonique et/ou bêta,
– dosimètres de zone pour l'estimation de la dose effective:	$H^*(10)$ dû au rayonnement photonique,
– dosimètres de zone pour l'estimation de la dose destinée au cristallin utilisée dans les champs de rayonnement purement photonique:	$H'(0,07)$ ou $H'(3)$ dû au rayonnement photonique,
– dosimètres de zone pour l'estimation de la dose destinée au cristallin utilisée dans les champs de rayonnement bêta et/ou des champs mixtes de rayonnements bêta et photonique:	$H'(3)$ dû aux rayonnements bêta et photonique,
– dosimètres de zone pour l'estimation de la dose destinée à la peau locale:	$H'(0,07)$ dû au rayonnement photonique.

Des règlements nationaux peuvent exiger que des types spécifiques de dosimètres mesurent un plus grand nombre de grandeurs.

NOTE 1 Behrens et Dietze (2010) fournissent des informations de base concernant le choix des grandeurs à mesurer pour la dosimétrie de cristallin.

NOTE 2 Dans le présent document, le terme "rayonnement bêta" est utilisé comme synonyme des rayonnements d'électrons et bêta.

Les exigences de performances des systèmes dosimétriques sont données dans les Tableaux 8 à 13 selon la grandeur à mesurer: $H_p(10)$: Tableau 8; $H_p(3)$: Tableau 9; $H_p(0,07)$: Tableau 10; $H^*(10)$: Tableau 11; $H'(3)$: Tableau 12; $H'(0,07)$: Tableau 13.

Les informations détaillées concernant certaines entrées des Tableaux 8 à 13 (à la fin du document) sont données dans les autres Tableaux 14 à 16 (à la fin du document).

Dans certains pays, la présence d'une dose de rayonnement bêta doit être indiquée par des dosimètres portés sur le tronc. Une telle indication de la présence d'une dose de rayonnement bêta ne constitue pas un mesurage. Pour cette raison, un paragraphe spécifique (11.9) concerne l'indication de la présence d'une dose de rayonnement bêta.

Un système dosimétrique n'est généralement pas capable de mesurer toutes les grandeurs indiquées ci-dessus. Ainsi, le système n'est soumis à l'essai qu'en ce qui concerne les grandeurs et les types de rayonnements pour lesquels il est destiné à être utilisé.

La pleine conformité au présent document est assurée si les exigences concernant les plages obligatoires indiquées dans les Tableaux 8 à 13 sont satisfaites. Si le client ou le fabricant exige des plages étendues, il convient alors d'effectuer également l'essai comme spécifié dans le présent document, c'est-à-dire que les exigences indiquées dans les Tableaux 8 à 13 s'appliquent également. La plage de toute grandeur d'influence mentionnée par le fabricant est appelée plage assignée. Ainsi, les systèmes dosimétriques peuvent être classés en fonction d'un ensemble de plages (par exemple pour les doses, les énergies, la température) dans lesquelles les exigences établies par le présent document sont satisfaites (Capacités du système, voir Article 7).

Pour les systèmes dosimétriques décrits ci-dessus, le présent document spécifie les caractéristiques générales, les procédures générales d'essai et les exigences de performances, les caractéristiques des rayonnements, de même que les caractéristiques environnementales, électriques, mécaniques, des logiciels et de sécurité.

Un système dosimétrique peut être soumis à l'essai en ce qui concerne différentes grandeurs à des moments différents. Si le système dosimétrique a été modifié depuis l'essai précédent, un nouvel essai concernant les grandeurs précédemment vérifiées peut s'avérer nécessaire.

L'étalonnage absolu du système dosimétrique n'est pas vérifié au cours d'un essai de type selon le présent document, puisque seules les propriétés du système présentent un intérêt. L'étalonnage absolu est vérifié pendant un essai individuel de série.

7 Capacité d'un système dosimétrique

7.1 Généralités

Les plages présentées dans les paragraphes suivants doivent être définies par le fabricant. Elles doivent être équivalentes ou plus étendues que les plages obligatoires qui sont données du Tableau 8 au Tableau 13. Le système dosimétrique doit satisfaire aux exigences de ces plages assignées.

Les plages assignées doivent être indiquées dans la documentation (manuel d'instructions) du système dosimétrique pour que son utilisateur soit informé des capacités de l'instrument.

7.2 Étendue de mesure et type de rayonnement

Selon la grandeur de dose, les limites de l'étendue de mesure doivent couvrir au moins les plages obligatoires données à la ligne 7 du Tableau 8 au Tableau 13.

Le ou les types de rayonnements pour lesquels le système dosimétrique est conçu doivent être indiqués.

Si le système dosimétrique n'est pas capable de mesurer $H_p(0,07)$ dû au rayonnement bêta en raison de toutes les énergies et de tous les angles d'incidence exigés (ceci signifie qu'il ne satisfait pas à 11.7.2), mais est en revanche capable d'indiquer la présence d'une dose de rayonnement bêta (ceci signifie qu'il satisfait à 11.9), ceci doit être indiqué.

7.3 Plages assignées des grandeurs d'influence

La plage assignée de toute grandeur d'influence doit être indiquée par le fabricant dans la documentation. La plage obligatoire de chaque grandeur d'influence est donnée dans la troisième colonne du Tableau 8 au Tableau 16. Toutes les exigences du présent document doivent être satisfaites sur toutes les plages assignées.

7.4 Temps de mesure maximal assigné t_{max}

Le fabricant doit indiquer la durée maximale d'une mesure de dose t_{max} pour laquelle les exigences du présent document sont satisfaites. Plus particulièrement, les exigences concernant le coefficient de variation doivent être satisfaites.

Cette durée doit être d'au moins un mois.

7.5 Réutilisation

Un dosimètre est considéré comme réutilisable tant que ses performances satisfont aux exigences du présent document. Si le dosimètre ne peut pas être réutilisé indéfiniment, ou si leur utilisation dépend de l'historique du dosimètre, ceci doit être indiqué par le fabricant. Le fabricant doit préciser les limites pour des utilisations répétées, c'est-à-dire une valeur maximale de dose à laquelle le dosimètre a été exposé et au-delà de laquelle il ne peut pas être réutilisé. En particulier, les exigences relatives au coefficient de variation doivent être satisfaites pour tous les dosimètres réutilisés.

NOTE Un exemple de limitation de la réutilisation est l'augmentation du signal zéro d'un détecteur TL après avoir reçu une dose élevée.

7.6 Fonction modèle

Le fabricant doit indiquer la forme générale de la fonction modèle pour un mesurage avec le dosimètre. Le fabricant peut utiliser l'exemple donné en 3.25 ou d'autres fonctions. Le fabricant doit indiquer les interdépendances éventuelles entre les variables de la fonction modèle. Les variables sont le coefficient d'étalonnage, les réponses relatives et les écarts.

NOTE D'autres informations détaillées relatives à la fonction modèle et à la détermination de l'incertitude de mesure sont fournies dans l'IEC TR 62461.

7.7 Exemple des capacités d'un système dosimétrique

Les nombres suivants sont choisis arbitrairement; ils couvrent au moins les plages obligatoires et ils diffèrent d'un système dosimétrique à un autre.

Le système dosimétrique peut être utilisé pour la mesure de $H_p(10)$ dû au rayonnement photonique:

Étendue de mesure: 0,05 mSv $\leq H_p(10) \leq$ 4 Sv. Le système dosimétrique est capable d'indiquer la présence d'une dose de rayonnement bêta.

Les plages d'utilisation pour les différentes grandeurs d'influence sont les suivantes.

- Énergie des photons et angle d'incidence: 50 keV à 1,4 MeV et 0° à ± 60°
- Température ambiante et humidité relative (pour les dosimètres): –15 °C à 50 °C et 40 % à 90 % HR

- Température ambiante (lecteur): +10 °C à +40 °C
- Exposition à la lumière (dosimètres et lecteur): jusqu'à 1 000 W/m^2
- Perturbations électromagnétiques (lecteur): plages obligatoires, voir Tableau 15
- Perturbations mécaniques: plages obligatoires, voir Tableau 16

Temps de mesure maximal assigné: 6 mois.

Les dosimètres du système dosimétrique sont réutilisables jusqu'à une irradiation à un équivalent de dose de plus de 200 mSv.

Fonction modèle: $M = \frac{N_0}{r_{\mathrm{n}} \cdot r_{E,\alpha} \cdot r_{\mathrm{env}}} \cdot [G - D_{\mathrm{EMC}} - D_{\mathrm{mech}}]$

où

M est la valeur mesurée;

N_0 est le coefficient d'étalonnage de référence;

r_{n} est la réponse relative due à la non-linéarité;

$r_{E,\alpha}$ est la réponse relative due à l'énergie et à l'angle d'incidence;

r_{env} est la réponse relative due aux influences de l'environnement;

G est la valeur indiquée par le système dosimétrique;

D_{EMC} est l'écart dû aux perturbations électromagnétiques;

D_{mech} est l'écart dû aux perturbations mécaniques.

Pour des informations détaillées, voir 3.22 et l'Annexe B.

8 Exigences pour la conception du système dosimétrique

8.1 Généralités

Les informations exigées dans cet Article 8 doivent être présentées par le fabricant sous forme écrite en vue de l'essai de type (pas nécessairement dans le manuel d'instructions). Les exigences indiquées peuvent être facilement vérifiées par examen visuel du système dosimétrique en fonctionnement.

8.2 Indication de la valeur de la dose (système dosimétrique)

La valeur indiquée doit être donnée en unités d'équivalent de dose, par exemple, en microsieverts (µSv). L'affichage ou l'enregistrement de dose doit aussi clairement indiquer la grandeur mesurée.

Si le lecteur permet une modification de la plage, cette modification doit être automatique.

À des valeurs de doses supérieures ou égales à dix fois la limite inférieure de l'étendue de mesure, c'est-à-dire pour $H \geq 10 \cdot H_{\mathrm{min}}$ la valeur indiquée doit être affichée avec une résolution de plus de 2 %. À la limite inférieure de l'étendue de mesure, H_{min}, une valeur de 10 % est suffisante.

NOTE Une solution technique possible est un affichage numérique: au moins deux chiffres significatifs sont affichés à la limite inférieure de l'étendue de mesure H_{min}. Par exemple, pour H_{min} = 0,1 mSv, l'affichage indique 0,10 mSv. Au-dessus de $10 \cdot H_{\mathrm{min}}$, trois chiffres significatifs s'affichent: 1,00 mSv.

8.3 Attribution de la valeur de dose au dosimètre (système dosimétrique)

Chaque valeur indiquée doit être attribuée individuellement au dosimètre (numéro) selon son origine.

NOTE Une solution technique possible est la suivante: l'attribution, lors du retrait des détecteurs du dosimètre, s'effectue avec la plus grande attention. Après évaluation des données, le numéro du dosimètre et la valeur indiquée constituent un ensemble de données qui est toujours manipulé d'un seul bloc.

8.4 Informations données sur l'instrumentation (lecteur et dosimètre)

Les informations suivantes doivent être clairement visibles sur le lecteur (a) à d)), sur le dosimètre, (a) à g)), s'il existe un espace suffisant sur le dosimètre:

a) une identification attribuant le lecteur et le dosimètre au système dosimétrique;

b) la grandeur mesurée et l'étendue de mesure;

c) le type de rayonnement (par exemple photonique et/ou bêta) correspondant au dosimètre;

d) la plage assignée d'énergie des particules;

e) sur les dosimètres individuels uniquement: s'il est possible de l'utiliser dans deux orientations ou plus, le dosimètre doit alors satisfaire aux exigences du présent document dans toutes les orientations ou il doit être clairement indiqué sur ce dosimètre la bonne orientation ou que son utilisation dans la mauvaise orientation peut conduire à des résultats erronés;

f) sur le dosimètre uniquement: le point de référence et l'orientation de référence du dosimètre (ou dans le manuel);

g) sur le dosimètre uniquement: un numéro d'identification lisible par l'utilisateur (obligatoire);

NOTE Par exemple, pour les points b) à d): 0,1 mSv ≤ $H_p(0,07)$ ≤ 3 Sv; 65 keV ≤ E_{ph} ≤ 1,4 MeV; 0,24 MeV ≤ E_{beta} ≤ 0,8 MeV.

8.5 Rétention et élimination de la contamination radioactive (dosimètre)

Dans la mesure où la pratique le permet, il convient que le dosimètre soit conçu pour réduire le plus possible la rétention de la contamination et faciliter son élimination. Un dosimètre peut être équipé d'une couverture protectrice supplémentaire. Toutefois, même avec cette protection, il doit toujours satisfaire aux exigences du présent document.

8.6 Algorithme d'évaluation de la valeur indiquée (système dosimétrique)

Pour l'essai de type selon le présent document, le fabricant doit fournir l'algorithme d'évaluation pour la valeur indiquée, à partir du ou des signaux du ou des détecteurs. La documentation doit être sous une forme permettant la bonne compréhension des calculs et/ou de l'arbre de décision.

Si plus d'un signal est utilisé pour évaluer la valeur indiquée pour l'essai de type, le fabricant doit prévoir la possibilité de lire séparément les signaux du ou des détecteurs.

NOTE Des informations détaillées sur le signal, la valeur évaluée et l'algorithme d'évaluation sont données à l'Annexe B.

Cet algorithme peut être confidentiel et être utilisé uniquement par le laboratoire d'essai pour les besoins des essais de type.

8.7 Utilisation des dosimètres en champs mixtes de rayonnement (système dosimétrique)

Si un dosimètre est utilisé dans des champs de rayonnement pour lesquels il n'est pas conçu, par exemple un dosimètre photonique utilisé dans un champ mixte photonique et neutronique, l'effet du rayonnement non destiné à être mesuré doit être établi par le fabricant dans le manuel, voir l'Article 9. Dans l'exemple mentionné, le rayonnement neutronique est une grandeur d'influence pour le dosimètre conçu pour le rayonnement photonique. Le fabricant doit indiquer la réponse au rayonnement neutronique pour les neutrons thermiques et un ou plusieurs domaines de sources de radionucléides de référence définis dans l'ISO 8529.

À partir de cette information, l'utilisateur, avec l'aide d'un second dosimètre destiné à mesurer le rayonnement neutronique, peut déterminer l'influence sur la dose totale.

9 Manuel d'instructions

9.1 Généralités

Un manuel d'instructions doit être fourni. Il doit être marqué de telle sorte qu'il se rapporte sans ambiguïté au système dosimétrique décrit. De telles consignes d'utilisation doivent être fournies pour chaque système dosimétrique. Les consignes d'utilisation doivent contenir la description de la construction, de la fonction, du fonctionnement et de la manipulation du système dosimétrique et de ses composants, y compris de l'utilisation du logiciel utilisé pour le contrôle du système dosimétrique et des données mémorisées.

9.2 Spécification des données techniques

Système dosimétrique en général:

– nom du fabricant ou marque déposée (si le système est fabriqué comme un tout);
– type de système dosimétrique et principe de fonctionnement;
– schéma de principe du système dosimétrique comportant le matériel, le logiciel et les données;
– nom du logiciel du système dosimétrique et numéro d'identification (voir 10.3);
– description des fonctionnalités et de tous les menus et sous-menus du logiciel;
– informations détaillées de fonctionnement, maintenance et procédures d'étalonnage;
– si l'algorithme d'évaluation n'est pas additif, un commentaire selon la Note 3 de 12.1.

Lecteur:

– nom du fabricant ou marque déposée;
– type de lecteur;
– exigences d'alimentation électrique;
– temps de stabilisation du lecteur;
– référence à la nécessité d'un balayage de gaz sur le dosimètre ou sur des parties du dosimètre au cours de sa lecture;
– mise en garde contre un stockage prolongé, si l'humidité élevée de l'air peut être source de détérioration.

Dosimètre:

– nom du fabricant ou marque déposée;
– type de dosimètre;
– type de détecteur(s);
– type de rayonnement pour la mesure duquel le dosimètre est conçu;

- point de référence du dosimètre;
- direction de référence pour l'étalonnage;
- orientation de référence par rapport aux sources de rayonnement et orientation de référence par rapport au porteur;
- dessin des dosimètres incluant les détecteurs et les matériaux de filtrage;
- épaisseur physique des parois autour des volumes sensibles (mg cm^{-2});
- masse et dimensions du dosimètre;
- méthode de nettoyage et de séchage du dosimètre;
- méthode d'effacement de la dose ("remise à zéro") du dosimètre.

Caractéristiques dosimétriques:

- grandeur mesurée;
- étendue de mesure et variation de la réponse due à la non-linéarité;
- coefficient de variation en fonction de l'équivalent de dose;
- temps de mesure maximal assigné;
- réponse au rayonnement environnemental naturel, voir 13.4;
- réponse relative en fonction de l'énergie du rayonnement et de l'angle d'incidence (pour les rayonnements bêta et photonique);
- plages assignées de toutes les autres grandeurs d'influence et variation correspondante de la réponse relative ou écart (voir 7.2 à 7.6, un exemple est donné en 7.7);
- réponse relative due au rayonnement non destiné à être mesuré (par exemple, le rayonnement neutronique), voir 8.7;

10 Logiciels, données et interfaces du système dosimétrique

10.1 Généralités

La version finale des logiciels doit être disponible dès le début de l'essai de type, étant donné qu'une grande partie de l'essai concernant les logiciels est indirectement couverte par l'essai métrologique. Pour cette raison, une modification de la partie dépendant des données du logiciel après l'essai de type n'est pas admise (voir ci-dessous pour la partie dépendant des données).

NOTE Les exigences suivantes sont basées sur le guide logiciel 7.2 de la European cooperation in legal metrology (WELMEC) (Coopération européenne dans le domaine de la métrologie légale) et mettent en œuvre la classe de risque C du guide 7.2. Le guide WELMEC peut servir d'information complémentaire. Toutefois, seules les exigences spécifiées dans cet Article 10 sont pertinentes.

Les exigences doivent empêcher toute modification involontaire des logiciels ou des données. De plus, toute modification volontaire des logiciels ou des données à l'aide d'un éditeur doit être empêchée. Au plus, une valeur indiquée peut être perdue du fait de toute modification des logiciels ou des données.

Les exigences doivent être appliquées uniquement lorsque le système dosimétrique est utilisé dans un cadre officiel, par exemple le contrôle radiologique individuel exigé d'un point de vue légal.

Lorsque l'essai de type selon le présent document a démarré, aucune donnée, aucun tableau ou aucun logiciel ne peuvent être modifiés ou supprimés.

L'essai de la partie dépendant des données du logiciel peut être très complexe. Toutefois, il ne doit pas monopoliser une partie importante du temps d'essai. Par conséquent, une grande part de responsabilité est laissée au fabricant, par l'intermédiaire de sa documentation, voir 10.10, pour la réalisation des essais. Néanmoins, quelques essais simples et pratiques

sont réalisés pour assurer que les fonctionnalités correspondent à celles décrites dans la documentation.

10.2 Conception et structure des logiciels

10.2.1 Exigences

Le logiciel doit être conçu de manière à ne pas être affecté par d'autres logiciels à moins que l'utilisation correcte du système ne l'exige.

NOTE Une solution technique possible consiste à séparer le logiciel en deux parties. Une partie contient toutes les fonctions nécessaires pour contrôler le lecteur et pour évaluer, mémoriser et afficher les valeurs indiquées. Cette partie est la "partie dépendant des données". L'autre partie du logiciel, la "partie ne dépendant pas des données", contient, par exemple, des statistiques relatives à la fréquence de certaines valeurs de la dose. La partie dépendant des données comporte des fonctions bien définies (interface de logiciel) qui sont utilisées pour communiquer avec les parties ne dépendant pas des données du logiciel. Ce concept technique de logiciel séparé présente l'avantage de permettre des modifications de la "partie ne dépendant pas des données" sans influencer la "partie dépendant des données".

10.2.2 Méthode d'essai

Documentation: Les mesures décrites pour protéger le logiciel doivent être plausibles compte tenu du type de système d'exploitation de l'ordinateur.

Réalisation de l'essai: Garantir que le logiciel est un fichier exécutable. En cas de séparation du logiciel (voir la Note en 10.2.1), les différentes parties du logiciel doivent être des fichiers séparés (par exemple, des bibliothèques de liaisons dynamiques (DLL – *dynamic link libraries*)).

10.3 Identification du logiciel

10.3.1 Exigences

La "partie dépendant des données" du logiciel (voir la Note en 10.2.1) doit être identifiée par un numéro. Il doit être possible d'afficher ce numéro d'identification au cours du fonctionnement du logiciel. Cette identification peut être comparée à celle donnée dans le rapport d'essai ou dans la notice d'utilisation. Le numéro d'identification doit changer automatiquement en cas de modification du logiciel (un simple numéro de version ne suffit pas).

NOTE 1 Dans le cas d'un code modulaire, plusieurs identifications peuvent être constituées pour les différents modules.

NOTE 2 Une solution technique possible est une somme de contrôle, au moins un contrôle de redondance cyclique utilisant une longueur polynomiale de 17 bits (CRC-16) avec une valeur de départ secrète cachée dans le fichier exécutable portant sur la totalité du logiciel.

10.3.2 Méthode d'essai

Documentation: La méthode permettant de garantir que l'identification du logiciel est modifiée par toute modification du logiciel doit être plausible.

Réalisation de l'essai: Garantir que les identifications peuvent être affichées pendant que le logiciel est en fonctionnement comme décrit dans le manuel d'instructions et qu'elles sont identiques à celles données dans ce manuel.

10.4 Authenticité du logiciel et présentation des résultats

10.4.1 Exigences

La protection doit couvrir aussi bien les actions involontaires (erreur d'utilisation) que les actions intentionnelles (manipulation) au moyen d'un éditeur. En cas de modification du logiciel, le programme doit s'arrêter au démarrage avec un message tel que "Violation de l'authenticité du logiciel, modification du programme non autorisée!". L'authenticité des

résultats présentés doit être garantie et les résultats doivent être clairement identifiés comme résultats pertinents du mesurage. Ils doivent par ailleurs être clairement distincts de toute information complémentaire.

Cette exigence a pour objet d'empêcher toute commande du lecteur ou du dosimètre par un logiciel autre que celui soumis à l'essai de type.

NOTE Une solution technique possible est la suivante:

Le code programme est un format exécutable (.exe). Une signature numérique est vérifiée au démarrage du logiciel. En cas de non-conformité, le logiciel ne démarre pas. La fenêtre du programme en cours est rafraîchie périodiquement et contrôle qu'il est toujours visible.

10.4.2 Méthode d'essai

Documentation: Les mesures destinées à empêcher toute modification du logiciel doivent être plausibles (par exemple, l'évaluation d'une somme de contrôle). Vérifier que les ensembles de données légalement applicables peuvent être uniquement produits par le logiciel dépendant des données soumis à l'essai de type.

Réalisation de l'essai: Modifier la suite des valeurs (par exemple afficher des "mSv" au lieu de "µSv") dans le code exécutable à l'aide d'un éditeur et faire fonctionner le logiciel. S'il démarre, l'exigence n'est pas satisfaite. Estimer par un contrôle visuel que des informations complémentaires sur l'écran ou l'impression ne peuvent pas être confondues avec les informations appartenant aux données de mesure pertinentes et que toutes les données pertinentes sont présentées.

10.5 Alarme et arrêt du système dans des conditions anormales de fonctionnement

10.5.1 Exigences

Dans le cas de conditions anormales de fonctionnement apparaissant dans les composants du système, le fonctionnement du système dosimétrique doit être interrompu automatiquement et une alarme (sonore et/ou visible) doit avertir l'opérateur. Ces conditions anormales de fonctionnement comprennent celles qui induisent de fausses lectures ou la perte de l'information de dose, par exemple une coupure de haute tension pour un tube photomultiplicateur, l'absence de papier dans l'imprimante, la température de chauffage du lecteur inférieure ou supérieure à la plage normale de températures de fonctionnement, le passage hors de portée d'un réseau local sans fil (WLAN – *wireless local area network*), voire l'arrêt du logiciel qui commande le mesurage.

Pas plus d'une valeur indiquée ne doit être perdue du fait de conditions anormales de fonctionnement. Si la valeur indiquée ne satisfait pas aux exigences du présent document en raison de conditions anormales de fonctionnement, cette valeur doit être accompagnée d'un message d'erreur. Une valeur au maximum doit être acceptée comme erronée par occurrence de condition anormale de fonctionnement si une réévaluation du dosimètre n'est pas possible. Si une réévaluation est possible, la nouvelle valeur indiquée doit satisfaire aux exigences du présent document.

10.5.2 Méthode d'essai

Documentation: Les mesures pour reconnaître un fonctionnement défectueux doivent être plausibles.

Réalisation de l'essai: Simuler des dysfonctionnements du matériel au cours de la lecture, par exemple déconnecter l'alimentation du système de chauffage, mettre un réseau local sans fil (WLAN) hors de portée, ou déconnecter le câble de transmission des données entre le lecteur et l'ordinateur. Si plusieurs valeurs indiquées sont perdues ou accompagnées d'un message d'erreur par défaillance simulée du matériel du fait d'une condition anormale de fonctionnement, l'exigence n'est pas satisfaite. Si une réévaluation est possible, la nouvelle valeur indiquée doit satisfaire aux exigences du présent document.

10.6 Contrôle des données d'entrée par le système dosimétrique

10.6.1 Exigences

Toutes les valeurs utilisées pour la détermination de la valeur indiquée, par exemple les coefficients d'étalonnage, le courant d'obscurité d'un photomultiplicateur ou la haute tension d'un photomultiplicateur doivent être sous le contrôle du système dosimétrique.

NOTE Une solution technique possible consiste à garantir que ces valeurs relèvent des plages fixées.

10.6.2 Méthode d'essai

Documentation: La méthode permettant de garantir que les paramètres de l'instrument relèvent de leurs plages admises doit être plausible.

Réalisation de l'essai: Tenter de modifier certains paramètres de l'instrument pour qu'ils ne relèvent plus de leur plage, par exemple la haute tension du tube photomultiplicateur ou la pression d'azote. Si plusieurs détecteurs sont lus par erreur simulée de plage, l'exigence n'est pas satisfaite.

10.7 Mémorisation des données

10.7.1 Exigences

a) Paramètres des instruments: L'utilisateur ne doit pas pouvoir modifier les paramètres des instruments (par exemple les coefficients d'étalonnage, la plage de haute tension d'un tube photomultiplicateur). Exception: Il doit n'être possible de modifier les paramètres des instruments que par l'intermédiaire des accès prévus par le logiciel (par exemple, mesure d'étalonnage ou entrée de données par un utilisateur autorisé par un mot de passe dont la valeur par défaut est définie dans le manuel d'instructions et qui peut être modifié par l'utilisateur). Un historique des valeurs et modifications de tous les paramètres doit être disponible pour l'utilisateur.

NOTE 1 Une solution technique possible est la suivante:

Toutes les données constituent des ensembles de données bien définis. La totalité de l'ensemble de données est protégée par une signature numérique. Le logiciel lit l'ensemble de données, calcule la signature numérique et la compare à sa valeur nominale contenue dans l'ensemble de données. Si une modification quelconque est détectée dans un ensemble de données, celui-ci est marqué par le programme comme étant invalide et n'est plus utilisé.

b) Résultats de mesure: Tous les résultats de mesure, y compris toutes les informations pertinentes nécessaires pour assurer la traçabilité et reconstituer le mesurage ayant produit le résultat mémorisé (authenticité) doivent être enregistrés ou mémorisés automatiquement après chaque mesurage, sans aucune modification. Ils contiennent au moins la date et l'heure de la lecture, l'identification du dosimètre (par exemple son numéro) et du lecteur, la valeur indiquée et les coefficients d'étalonnage utilisés. Ces données peuvent être produites sur des documents imprimés ou mémorisées sous forme électronique sur un disque dur en liaison avec un logiciel pour l'affichage des données: programme de visualisation qui est un "programme dépendant des données", voir Note en 10.2.1. Ce logiciel ne doit pas utiliser (par exemple, afficher ou imprimer) des données modifiées. De plus, la mémorisation à long terme doit avoir une capacité suffisante pour l'utilisation prévue. Les données doivent être protégées contre les risques de perte.

NOTE 2 Une solution technique possible est la suivante:

Toutes les données spécifiques à un mesurage particulier constituent des ensembles de données bien définis et mémorisés dans un format binaire automatiquement après le mesurage. La totalité de l'ensemble de données est protégée par une signature numérique. Cet ensemble de données ne doit pas contenir les paramètres des instruments, mais uniquement les informations permettant d'indiquer les conditions de mise à disposition des paramètres réels des instruments, par exemple le nom de fichier, l'emplacement et la date et l'heure du fichier. Le programme de visualisation lit les données mémorisées et vérifie leur signature numérique. Si une modification quelconque est détectée dans un ensemble de données, celui-ci est marqué par le programme comme étant invalide et n'est plus utilisé. Les données sont mémorisées sur deux disques durs supervisés par un contrôleur RAID. Le logiciel active la protection en écriture du système d'exploitation.

10.7.2 Méthode d'essai

Documentation: Le mode de mémorisation des données et des mesures destinées à prévenir toute modification ou perte de ces données, par exemple la procédure d'évaluation d'une somme de contrôle, doit être apparemment efficace (par exemple, il doit couvrir la totalité de l'ensemble de données et une formule permettant de calculer la capacité de mémoire restante doit être appliquée). Toutes les informations pour assurer la traçabilité et reconstituer le mesurage doivent être incluses. En cas d'utilisation d'une signature numérique, le logiciel de lecture et d'affichage des données (programme de visualisation) doit la vérifier.

Réalisation de l'essai:

a) Garantir la mémorisation dans un fichier de données de toutes les données pertinentes nécessaires pour reconstituer le mesurage juste après un mesurage. Garantir également l'absence de bouton ou de menu pour interrompre ou désactiver la mémorisation automatique.

b) Tenter de modifier les paramètres de l'instrument ou les valeurs indiquées par l'intermédiaire du logiciel lui-même. Si cette opération est possible sans connaissances particulières, par exemple un mot de passe ou des informations détaillées sur la structure du logiciel, l'exigence n'est pas satisfaite.

c) Ouvrir un fichier de données à l'aide d'un éditeur et modifier quelques bits isolés, puis fermer le fichier. Si le logiciel du système dosimétrique continue à lire le fichier de données et fournit les valeurs modifiées, l'exigence n'est alors pas satisfaite.

d) Tenter d'effacer le fichier de données du disque dur en utilisant une commande normale du système d'exploitation. Si cette opération est possible sans avertissement ou connaissances particulières, par exemple un mot de passe ou des informations détaillées sur la structure du logiciel, l'exigence n'est pas satisfaite.

e) Vérifier qu'un avertissement est donné et que le mesurage est interrompu dans le cas où la mémoire est pleine ou retirée.

f) Dans le cas où les données sont imprimées et mémorisées, assurer leur caractère identique dans les deux cas.

Pour la mémorisation des données à long terme, il est nécessaire de prendre en considération la durée limitée de lecture (par exemple quelques années) des formats de données particuliers (par exemple un CD ou un DVD).

10.8 Transmission des données

10.8.1 Exigences

Dans le cas où les données sont transmises d'un dispositif à un autre (par exemple d'un lecteur à un PC), ces données doivent contenir toutes les informations nécessaires à la poursuite correcte de leur traitement. La modification, la suppression ou l'ajout de quelque élément que ce soit à ces données ne doit pas être possible. De plus, la partie réceptrice du système dosimétrique, par exemple l'ordinateur, doit garantir que les données reçues sont authentiques. Cela signifie que la provenance éventuelle des données d'un autre appareil que le lecteur ou le dosimètre attribué au système dosimétrique doit être reconnue. Dans le cas où la connexion entre les parties impliquées dans une transmission est indisponible ou retarde la transmission, une valeur indiquée au plus doit être perdue. Dans le cas d'un ensemble de données transmis de manière incorrecte (bien que le protocole de transmission ait tenté de répéter la transmission jusqu'à ce qu'elle aboutisse), cet ensemble de données ne doit pas être utilisé.

NOTE Une solution technique possible est la suivante:

Toutes les données transmises constituent des ensembles de données bien définis incluant la date et l'heure de création de l'ensemble de données, un numéro d'exécution, une identification de la partie émettrice, par exemple le numéro de série du lecteur et les données correspondantes. La totalité de l'ensemble de données est protégée par une signature numérique. Le lecteur chiffre les données transmises au logiciel avec une clé connue uniquement du logiciel soumis à l'essai de type (par exemple son code de hachage) lors d'une séquence d'établissement de liaison. La partie réceptrice, par exemple l'ordinateur, vérifie les données en garantissant

qu'aucun numéro d'exécution ne manque (ou est en double) et que l'identification de la partie émettrice est correcte. Dans le cas d'un ensemble de données transmis incorrect, celui-ci est marqué par le programme comme étant invalide et n'est plus utilisé.

10.8.2 Méthode d'essai

Documentation: Toutes les informations nécessaires pour assurer la traçabilité et pour poursuivre le traitement des données de mesure doivent être contenues dans l'ensemble de données. En cas d'utilisation d'une signature numérique, le logiciel de réception des données doit la vérifier. Les données secrètes (par exemple la valeur initiale de la clé le cas échéant) doivent le rester vis-à-vis d'outils simples d'espionnage (piratage). Vérifier que les données possèdent une signature numérique pour garantir leur identification correcte et leur authentification.

Réalisation de l'essai: Des vérifications ponctuelles doivent indiquer qu'aucune donnée pertinente n'est perdue du fait d'une interruption de transmission (par exemple, déconnexion d'un câble ou mise hors de portée d'un réseau local sans fil (WLAN)).

10.9 Interfaces matérielles et interfaces logicielles

10.9.1 Exigences

L'influence des commandes saisies ou des valeurs reçues avec les interfaces (par exemple, des interfaces utilisateur telles qu'un clavier, des interfaces logicielles, un lecteur de codes à barres, un lecteur RFID et des mises à jour par liaison radio) sur les données et fonctions de l'instrument doit se limiter aux seules influences admissibles. Toutes les commandes ou valeurs doivent être définies, c'est-à-dire soit elles doivent avoir un sens et leur traitement par l'instrument doit être possible, soit l'instrument doit les identifier comme invalides. Les commandes invalides ne doivent avoir aucun effet, quel qu'il soit, sur les données et fonctions de l'instrument.

NOTE 1 En principe, il est possible de contourner une interface logicielle. Cela peut habituellement être exclu par séparation du logiciel (voir Note en 10.2.1), quand la partie dépendant des données du logiciel est réalisée dans un fichier binaire séparé.

NOTE 2 Une solution technique possible est:

Interfaces utilisateurs: Un module dans le logiciel dépendant des données élimine les commandes inadmissibles. Seul ce module reçoit des commandes et il n'y a pas de dérogation possible. Toute entrée erronée est bloquée. Quand il entre des commandes, l'utilisateur est sous le contrôle d'un module logiciel spécifique ou guidé par celui-ci. Ce module de guidage est indissociable du module qui élimine les commandes inadmissibles.

Interfaces logicielles: Un module logiciel reçoit et interprète les commandes de l'interface. Ce module appartient au logiciel dépendant des données. Il ne transmet que les commandes autorisées aux autres modules logiciels dépendant des données. Toutes les commandes inconnues ou non autorisées sont rejetées et n'ont pas d'incidence sur le logiciel dépendant des données ou sur les données de mesure.

10.9.2 Méthode d'essai

Documentation: La liste des commandes et paramètres acceptés par les interfaces matérielles et les interfaces logicielles doit être apparemment complète. Par exemple, s'il n'est pas possible de réaliser un étalonnage sur la base de cette liste et des informations concernant la structure du logiciel, la liste ne peut être complète.

Réalisation de l'essai: En utilisant le logiciel fourni et les équipements périphériques, effectuer les essais pratiques (vérifications ponctuelles) avec les commandes documentées et également les commandes non documentées, et vérifier par essai toutes les commandes de menus éventuelles. Si un logiciel accessoire accompagne le système dosimétrique pour utiliser l'interface avec un ordinateur supplémentaire, pour certaines des commandes disponibles, il doit être vérifié que le système dosimétrique fonctionne comme indiqué dans la documentation. De plus, certaines autres commandes doivent être fournies. Si ces dispositions affectent le système dosimétrique, l'exigence n'est pas satisfaite.

10.10 Documentation pour l'essai concernant le logiciel

10.10.1 Exigences

a) Documentation du manuel d'instructions: Toutes les parties concernant la dosimétrie, les menus et sous-menus du logiciel, y compris le programme de visualisation pour la lecture et l'affichage des données mémorisées, doivent être décrits dans le manuel d'instructions, voir l'Article 9.

b) Documentation pour l'essai de type: Outre la documentation du manuel, les informations suivantes doivent être données par le fabricant pour l'essai de type:

- une description de la structure du logiciel, incluant les fonctions logicielles dépendant des données et la signification de ces données; en cas de séparation logicielle, une description de l'interface logicielle; les mesures pour protéger le logiciel; voir 10.2;
- la méthode pour reconnaître le numéro d'identification, voir 10.3;
- les mesures pour empêcher toute modification du logiciel et des données présentées et comment leur authenticité est garantie, voir 10.4;
- les mesures pour reconnaître les pannes de fonctionnement, voir 10.5;
- une liste de tous les paramètres, leurs plages et leurs valeurs nominales, la méthode permettant de garantir que les paramètres relèvent des plages autorisées, leur emplacement de mémorisation et comment ils peuvent être visualisés, y compris leur historique; voir 10.6;
- la méthode de mémorisation automatique des données; une description de tous les champs d'un ensemble de données; la méthode utilisée pour garantir leur authenticité; la gestion des cas exceptionnels lors de la mémorisation de données (par exemple mémorisation complète); la méthode du programme de visualisation pour détecter les corruptions; les mesures pour empêcher toute modification ou perte des données mémorisées; voir 10.7;
- la méthode de transmission des données; une description de tous les champs d'un ensemble de données; la méthode utilisée pour garantir leur authenticité; la gestion des cas exceptionnels lors de la transmission de données (par exemple un câble déconnecté); les mesures pour empêcher toute modification, perte ou ajout aux données transmises, voir 10.8;
- une description de l'interface logicielle, en particulier quels domaines de données réalisent l'interface; une liste complète des commandes et paramètres acceptés par les interfaces matérielles et les interfaces logicielles, comportant une déclaration d'exhaustivité de cette liste et une description succincte de chaque commande; voir 10.9;
- les caractéristiques nécessaires du système d'exploitation et du matériel de l'ordinateur;
- une présentation générale des aspects de sécurité du système d'exploitation, par exemple, la protection, les comptes ou privilèges des utilisateurs.

Ces informations peuvent être confidentielles et utilisées uniquement par le laboratoire d'essai pour les besoins des essais de type.

10.10.2 Méthode d'essai

Documentation: Vérifier que toute la documentation exigée en 10.10.1 est complète, disponible et conforme à son objectif.

Réalisation de l'essai: En utilisant le logiciel au cours de l'essai de type, de nombreux menus sont utilisés. Tous les menus doivent être documentés dans le manuel d'instructions. Le reste des menus doit être vérifié en "jouant" sur le logiciel en fonctionnement et en comparant les parties correspondantes du manuel d'instructions. Si tous les menus figurant dans le logiciel et dans le manuel d'instructions ne correspondent pas, l'exigence n'est pas satisfaite.

11 Exigences de performances et essais sous rayonnement (système dosimétrique)

11.1 Généralités

Toutes les grandeurs d'influence considérées dans cet article sont de type F, voir 3.16.

Si le système dosimétrique utilise plusieurs signaux pour l'évaluation de la valeur indiquée, l'Article 12 doit être considéré. Les informations nécessaires pour l'essai selon l'Article 12 doivent être obtenues au cours des essais selon l'Article 11.

Si le système dosimétrique est destiné à mesurer à la fois le rayonnement photonique et le rayonnement bêta et s'il utilise le même signal pour l'évaluation de la valeur indiquée pour les deux types de rayonnements, la même qualité de rayonnement de référence doit alors être choisie pour les deux types de rayonnements.

Ceci correspond à la pratique: Si un seul signal (et donc un détecteur) est utilisé, un seul coefficient d'étalonnage peut être appliqué. Ce coefficient est le même à la fois pour le rayonnement photonique et le rayonnement bêta. Ainsi, la qualité du rayonnement de référence doit être la même pour la dépendance en énergie des particules, l'angle d'incidence et le type de rayonnement.

11.2 Coefficient de variation

Les fluctuations statistiques de la valeur indiquée doivent satisfaire aux exigences de la ligne 6 du Tableau 8 au Tableau 13.

L'essai doit être réalisé conjointement avec l'essai concernant la non-linéarité. Par conséquent, la méthode d'essai est décrite au 11.3 suivant.

11.3 Non-linéarité

11.3.1 Exigences

La variation de la réponse due à une modification de l'équivalent de dose ne doit pas être supérieure aux valeurs données à la ligne 7 du Tableau 8 au Tableau 13 sur l'ensemble de l'étendue de mesure des rayonnements de référence photoniques et/ou bêta.

11.3.2 Méthode d'essai

a) Source à utiliser

Les essais doivent être réalisés avec un rayonnement de sources de ^{137}Cs or ^{60}Co ou autres qualités de rayonnements spécifiées dans la série ISO 4037. Si le dosimètre comporte des détecteurs séparés pour le rayonnement photonique et le rayonnement bêta, l'essai doit être réalisé avec une source de rayonnement bêta également, par exemple ^{90}Sr/^{90}Y. Dans le cas où le signal des détecteurs dépend fortement de l'énergie des particules, c'est-à-dire $\max(r_{E,\alpha})/\min(r_{E,\alpha}) > 2$, l'essai doit également être réalisé en utilisant différentes qualités de rayonnements, par exemple, en plus avec des qualités de rayonnement photonique de faible énergie. Durant les essais, le dosimètre doit être irradié au rayonnement sur le fantôme exigé (voir 5.1.5) dans la direction de référence.

NOTE 1 Les irradiations peuvent être effectuées à l'air libre si le facteur de correction pour l'exposition à l'air libre est appliqué au lieu de celui appliqué sur le fantôme. Ce facteur de correction est spécifique au dosimètre en essai et à la qualité de rayonnement utilisée. Il est donc déterminé spécifiquement. Les irradiations à l'air libre peuvent être effectuées à des distances plus courtes donnant lieu à des diamètres de champs plus petits du fait que le fantôme omis ne doit pas être éclairé.

b) Essais à réaliser

Les essais doivent être réalisés séparément pour les rayonnements photoniques ou les rayonnements bêta (le type de rayonnement pour lequel le système dosimétrique est spécifié).

La réponse doit être mesurée pour au moins les valeurs de dose suivantes: à chaque limite de chaque ordre de grandeur de l'étendue de mesure, à environ 30 % de chaque ordre complet de grandeur, aux limites de l'étendue de mesure et être par ailleurs proches des variations de plage (si elles sont connues). Au total, n mesurages répétés de chacune des w valeurs de dose doivent être effectués.

NOTE 2 Lorsque, par exemple, l'étendue de mesure est comprise entre 0,1 mSv et 2 Sv au plus, les valeurs de dose correspondantes sont 0,1 et 0,3 mSv; 1 et 3 mSv; 10 et 30 mSv; 100 et 300 mSv; 1 Sv et 2 Sv

Pour chaque dose C_i, la valeur moyenne indiquée $\overline{G}_i$ et l'écart type s_i doivent être déterminés.

11.3.3 Interprétation des résultats

Si l'utilisation des w valeurs du coefficient de variation et des valeurs de c_1 et c_2 données dans le Tableau 2 indique que

- pour les valeurs de dose w – 2, le coefficient de variation est inférieur à c_1 fois les limites indiquées à la ligne 6 du Tableau 8 au Tableau 13 et
- pour les deux valeurs (de débit) de dose restantes – qui ne doivent pas être adjacentes – les coefficients de variation sont inférieurs à c_2 fois les limites indiquées à la ligne 6 du Tableau 8 au Tableau 13,

alors l'exigence de 11.2 est considérée comme satisfaite.

NOTE 1 Cette méthode d'essai est expliquée en détail dans le document de Brunzendorf et Behrens (2007), voir la bibliographie. Elle prend en compte le fait qu'il n'est pas possible de mesurer le coefficient de variation avec précision et facilement. Par conséquent, l'essai incorpore la méthode statistique d'un test de Khi-carré unilatéral. Un système dosimétrique ayant un coefficient de variation équivalent à 0,9 fois la limite exigée réussit l'essai avec une probabilité d'environ 80 %. Un système dosimétrique ayant un coefficient de variation équivalent à 1,1 fois la limite exigée échoue à l'essai avec une probabilité d'environ 80 %.

NOTE 2 Si l'interprétation des résultats est telle que "pour chaque dose C_i, la valeur $s_i / \overline{G}_i$ n'est pas plus élevée que la limite exigée indiquée à la ligne 6 du Tableau 8 au Tableau 13 (méthode d'essai en cours)", alors un système dosimétrique ayant un coefficient de variation équivalent à 0,9 fois la limite exigée échoue à l'essai avec une probabilité d'environ 98 %. Cela peut également s'expliquer ainsi: Si l'exigence de la méthode d'essai "$s_i / \overline{G}_i$ est plus élevée que la valeur exigée" est satisfaite avec une probabilité d'environ 85 %, alors le vrai coefficient de variation n'est pas plus élevé que 0,63 fois la limite exigée.

Si, par ailleurs, pour chacun des groupes résultants (valeurs de dose C_i), l'inégalité $r_{\text{min}} - U_{C,\text{com}} \leq \left(\frac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}} \right) \cdot \frac{C_{\text{r,0}}}{C_i} \leq r_{\text{max}} + U_{C,\text{com}}$ est valide, alors l'exigence de 11.3.1 est considérée comme satisfaite.

U_{com} est calculée selon l'Équation (A.5), Exemple 2. $U_{C,\text{com}}$ est l'incertitude relative élargie composée de $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U^2_{C,\text{rel; r,0}} + U^2_{C,\text{rel; }i}}$ avec les incertitudes relatives élargies $U_{C,\text{rel; r,0}}$ et $U_{C,\text{rel; }i}$ des valeurs conventionnelles de grandeur respectivement de $C_{\text{r,0}}$ et C_i pour les différentes qualités de rayonnement. Si $U_{C,\text{rel; r,0}}$ et $U_{C,\text{rel; }i}$ sont corrélées, ceci doit être pris en compte. Pour $U_{C,\text{rel}}$, voir 5.2.2.

Tableau 2 – Valeurs de c_1 et c_2 pour w valeurs de dose différentes et n indications pour chaque valeur de dose

w	Valeur de c_1 pour n égal à							Valeur de c_2 pour n égal à						
	4	**7**	**10**	**15**	**20**	**25**	**∞**	**4**	**7**	**10**	**15**	**20**	**25**	**∞**
5	1,000	1,007	1,009	1,009	1,009	1,009	1	1,499	1,400	1,344	1,290	1,255	1,231	1
6	1,058	1,051	1,046	1,039	1,035	1,032	1	1,572	1,454	1,389	1,326	1,287	1,261	1
8	1,147	1,117	1,100	1,084	1,074	1,067	1	1,687	1,536	1,458	1,383	1,336	1,304	1
10	1,215	1,166	1,141	1,117	1,102	1,092	1	1,772	1,597	1,508	1,423	1,372	1,335	1
12	1,269	1,205	1,173	1,143	1,124	1,112	1	1,840	1,645	1,548	1,455	1,399	1,360	1
14	1,315	1,238	1,200	1,164	1,142	1,128	1	1,895	1,684	1,578	1,480	1,421	1,379	1
16	1,351	1,265	1,222	1,182	1,158	1,142	1	1,940	1,716	1,605	1,502	1,440	1,396	1
18	1,388	1,289	1,242	1,211	1,171	1,153	1	1,980	1,743	1,628	1,409	1,453	1,409	1
20	1,418	1,311	1,259	1,233	1,183	1,164	1	2,015	1,767	1,646	1,394	1,466	1,421	1
25	1,483	1,355	1,295	1,240	1,210	1,186	1	2,081	1,812	1,683	1,563	1,445	1,444	1
50	1,683	1,494	1,407	1,328	1,283	1,252	1	2,275	1,945	1,789	1,646	1,561	1,504	1

11.4 Caractéristiques de surexposition, rémanence, et réutilisation

11.4.1 Exigences

Les exigences se subdivisent en trois parties:

a) Reconnaissance d'une surexposition

Lorsque le dosimètre est irradié avec une forte dose, comme indiqué à la ligne 8 du Tableau 8 au Tableau 13, le système doit afficher une dose indiquée plus grande que la limite supérieure de dose de l'étendue de mesure, H_{up}, ou un message de surexposition.

b) Rémanence

Si un dosimètre irradié à des doses élevées présente une rémanence sur les mesurages suivants, des dispositions appropriées doivent être prises pour assurer que les exigences du présent document sont satisfaites dans les mesurages suivants.

c) Réutilisation

Si les dosimètres ne peuvent être réutilisés indéfiniment ou si leur utilisabilité dépend de leur historique, le fabricant le précise, voir 7.5. Souvent, une dose élevée au cours de la dernière irradiation affecte négativement la réutilisation.

11.4.2 Méthode d'essai

Pour cet essai, quatre groupes de dosimètres doivent être exposés à une source de référence. Les essais doivent être réalisés avec un rayonnement des sources ^{137}Cs ou ^{60}Co ou autres qualités de rayonnement spécifiées dans la série ISO 4037.

Groupe 1: groupe de référence: n (≥ 5) dosimètres doivent être irradiés à $C_{r,0}$, voir le Tableau 7.

Groupe 2: au moins un dosimètre doit être irradié à un équivalent de forte dose comme indiqué à la ligne 8 du Tableau 8 au Tableau 13.

Groupe 3: n (≥ 10) dosimètres doivent être irradiés à un équivalent de dose égal à la limite inférieure de l'étendue de mesure, H_{min}.