BS EN 62387:2016

BSI Standards Publication

Radiation protection instrumentation — Passive integrating dosimetry systems for individual, workplace and environmental monitoring of photon and beta radiation

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National foreword

This British Standard is the UK implementation of EN 62387:2016. It is derived from IEC 62387:2012. It supersedes BS EN 62387-1:2012 which is withdrawn.

The CEN common modifications have been implemented at the appropriate places in the text. The start and finish of each common modification is indicated in the text by tags [C〉 〈C].

The title of this standard has also been modified by CEN.

The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Published by BSI Standards Limited 2016

ISBN 978 0 580 86060 7

ICS 13.280

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 March 2016.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62387

February 2016

ICS 13.280

English Version

Radiation protection instrumentation - Passive integrating dosimetry systems for individual, workplace and environmental monitoring of photon and beta radiation (IEC 62387:2012 , modified)

Instrumentation pour la radioprotection - Systèmes dosimétriques intégrés passifs pour la surveillance de l'individu et de l'environnement des rayonnements photoniques et bêta (IEC 62387:2012 , modifiée)

Strahlenschutz-Messgeräte - Passive integrierende Dosimetriesysteme zur Personen-, Arbeitsplatz- und Umgebungsüberwachung auf Photonen- und Betastrahlung (IEC 62387:2012 , modifiziert)

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 62387:2016 E

European foreword

This document (EN 62387:2016) consists of the text of IEC 62387:2012 prepared by IEC/SC 45B, "Radiation protection instrumentation", of IEC/TC 45, "Nuclear instrumentation" together with the common modifications prepared by CLC/TC 45B, "Radiation protection instrumentation".

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2017-01-04
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2019-01-04

This document supersedes EN 62387-1:2012.

Clauses, subclauses, notes, tables, figures and annexes which are additional to those in IEC 62387:2012 are prefixed “Z”.

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Endorsement notice

The text of the International Standard IEC 62387:2012 was approved by CENELEC as a European Standard with agreed common modifications.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIATION PROTECTION INSTRUMENTATION – PASSIVE INTEGRATING DOSIMETRY SYSTEMS FOR PERSONAL 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 standard cancels and replaces IEC 62387-1 published in 2007. This edition constitutes a technical revision.

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

- Extension of the photon energy range for dosemeters to measure $H_p(0,07)$ from the old range of 8 keV to 250 keV to the new range of 8 keV to 10 MeV.
- Addition of performance requirements for dosemeters to measure $H_p(3)$ for both photon and beta radiation. Such dosemeters can be used to monitor the eye lens dose.
- Addition of performance requirements for dosemeters to measure $H'(0,07)$ for both photon and beta radiation.
- Correction and clarification of several subsections to obtain a better applicability.

- Alignment of IEC performance requirements on dosimetry systems for measuring personal dose equivalents with the recommendations on accuracy stated in ICRP Publication 75, *General Principles for the Radiation Protection of Workers*. Further information is given in the new informative Annex E.

With these changes it also covers the scope of ISO 12794:2000, *Nuclear energy – Radiation protection – Individual thermoluminescence dosemeters for extremities and eyes*.

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

FDIS	Report on voting
45B/743/FDIS	45B/752/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 here 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;

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 FOR PERSONAL AND ENVIRONMENTAL MONITORING OF PHOTON AND BETA RADIATION

1 Scope

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

– the personal dose equivalent $H_p(10)$ (for whole body dosimetry),
– the personal dose equivalent $H_p(3)$ (for eye lens dosimetry),
– the personal dose equivalent $H_p(0,07)$ (for both whole body and extremity dosimetry),
– the ambient dose equivalent $H^*(10)$ (for environmental dosimetry), or
– the directional dose equivalent $H'(0,07)$ (for environmental dosimetry).

〖C〗 *Text deleted* 〖C〗

This standard 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. 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 standard

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

[a] The following beta radiation source 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] 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] 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).

NOTE 2 In this standard, “dose” means dose equivalent, unless otherwise stated.

NOTE 3 For $H_p(10)$ and $H^*(10)$ no beta radiation is considered. Reasons: 1) $H_p(10)$ and $H^*(10)$ are a conservative estimate for the effective dose which is not a suitable quantity for beta radiation. 2) No conversion coefficients are available in ICRU 56, ICRU 57 or ISO 6980-3.

NOTE 4 The maximum energy ranges are the energy limits within which type tests according to this standard are possible.

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 standard 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

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

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

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

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

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

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

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

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

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

ISO 4037 (all parts), *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, *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* 〈C〉

〈C〉 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)* 〈C〉

3 Terms and definitions

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

NOTE The terms are listed in alphabetical order.

3.1
ambient dose equivalent
$H^*(d)$
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]

3.2
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]

3.3
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)

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

[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]

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

2 IEC 60050-394 will be replaced by IEC 60050-395.

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
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

$$r_{\mathrm{n}} = \frac{R_{\mathrm{n}}}{R_0}$$

Note 1 to entry: For a linear dosimetry system, r_{n} is equal to unity.

3.6
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, modified – The symbol k has been added]

3.7
detector
radiation detector
apparatus or substance used to convert incident ionizing radiation energy into a signal suitable for indication and/or measurement

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, 394-24-01, modified – The term “detector” has been added as the first preferred term]

3.8
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

$$D = G - G_{\mathrm{r}}$$

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 60050-311:2001, 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]

3.9
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 in terms of $H'(d)$ is 0,07 mm and $H'(d)$ may be written as $H'(0,07)$. [IEV 393-14-96]

[SOURCE: ICRU 51]

3.10
dosemeter
radiation meter designed to measure the quantities 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. the direct ion storage (DIS) dosemeter).

3.11
dosimetry system
dosemeter, reader and all associated equipment and procedures used for assessing the indicated value

3.12
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 standard.

[SOURCE: GUM 2.3.5]

3.13
indicated value
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 to entry: For details, see Annex B of this standard.

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

3.14
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 length.

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 B.2.10, modified – Examples 1, 2 and 3 have been removed and Notes 1 and 2 to entry have been added]

3.15
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.

3.16
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.

3.17
lower limit of the measuring range
H_{low}
lowest dose value included in the measuring range

3.18
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 International Standard

Note 1 to entry: The mandatory ranges of the influence quantities dealt with in this International Standard are given in the second column of Tables 8 to 15.

3.19
maximum rated measurement time
t_{max}
longest continuous period of time over which the dose is accumulated and over which all requirements of this standard 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 (at TLDs) or a dose reset by means of software (at DIS).

3.20
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 3.23.

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

3.21
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 60050-311:2001, 311-03-12, modified – The original note has been replaced by a new Note 1 to entry]

3.22
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.
[IEV 393-14-97]

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

[SOURCE: ICRU 51]

3.23
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 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 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.

3.24
point of test
point in the radiation field at which the conventional true 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”]

3.25
preparation
normal treatment of dosemeters or detectors before a dose measurement, 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

3.26
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 60050-311:2001, 311-07-05, the term reads “nominal range of use”. In this standard, “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 60050-311:2001, 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]

3.27
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.

[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]

3.28
readout
process of measuring the stored dose information of a detector in a reader

3.29
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 60050-311:2001, 311-06-02, modified – After “uncertainties” the words “, or limits of error,” have been deleted and “dosimetry system” has replaced “measuring instrument”]

3.30
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]

3.31
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]

3.32
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

3.33
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.

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

3.34
relative expanded uncertainty
U_{rel}
expanded uncertainty divided by the measurement result

3.35
relative response
r
quotient of the response R and the reference response R_0

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

3.36
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 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, 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]

3.37
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 3.20) and a parameter characterizing the dispersion as *uncertainty* (see 3.41).

Note 2 to entry: The result of a measurement is related to the *indicated value given by the instrument* G (see 3.13) and to the values of correction obtained by calibration and by the use of a *model* (see 3.23).

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

[SOURCE: IEC 60050-311: 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 standard]

3.38
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 of this standard.

3.39
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 B.2.17, modified – The preferred term "standard deviation" has been added, as well as the symbol s, and the formula has been modified]

3.40
standard test conditions
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: 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. The deviations of the calibration factor from its value under reference conditions caused by these deviations should in principle be corrected for.

Note 2 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]

3.41
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]

3.42
type test
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-394:2007, 394-40-02]

3.43
upper limit of the measuring range
H_{up}
highest dose value included in the measuring range

〈C〉 **3.Z1**
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 $H'(0.07)$ or $H^*(10)$.

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

3.Z2
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 $H'(0.07)$ or $H^*(10)$.

3.Z3
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 $H'(0.07)$ or $H^*(10)$. 〈C〉

〈C〉 **3.Z4**
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, modified – "dose (rate)" has been added and Note 2 to entry has been added] 〈C〉

4 Units and symbols

In the present standard, 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).

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 standard 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, 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 value

The relative expanded uncertainty $U_{C,\mathrm{rel}}$ of the conventional true 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 3.12, 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 3.38) or detector (see 3.7) 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 standard is multiplied by the number of signals being used in different ranges.

NOTE 2 Examples:

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 standard have to be measured within its operating range, i.e. above a dose equivalent of 200 mSv.

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 standard 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 are 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 standard 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.

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 standard.

The performance requirements for dosimetry systems are given in Tables 8 to 12 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; $H'(0,07)$: Table 12.

Details for some of the entries in Tables 8 to 12 (at the end of the document) are given in the further 〚C〉 Tables 13 to 15 〈C〛 (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 standard is given if the requirements for the mandatory ranges given in Tables 8 to 12 are fulfilled. If the customer or manufacturer requires extended ranges then the test should also be performed as specified in this standard, i.e. the requirements given in Tables 8 to 12 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

standard 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 standard 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 standard 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 larger than the mandatory ranges that are given in Tables 8 to 12. 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 Tables 8 to 12.

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

In case the dosimetry system is not able to measure beta dose (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 Tables 8 to 15. All requirements of this standard 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 standard 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 standard. 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 a dose value above which dosemeters 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 3.23 or other functions. The manufacturer shall state any interdependencies between the variables of the model function. The variables are the calibration factor, the relative responses, and the deviations.

NOTE Z1 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 to another dosimetry system.

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 14
- Mechanical disturbances: mandatory ranges, see Table 15

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

where

M is the measured value;

N_0 is the reference calibration factor;

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 3.20 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 shall also clearly indicate the quantity being measured.

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

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 and dosemeter (on the dosemeter only if enough space is available):

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 the dosemeter: the reference point and reference orientation (or in the manual);

f) 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;

g) only on the dosemeter: an identification number that can be read by the user shall always be on the dosemeter;

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 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 standard.

8.6 Algorithm to evaluate the indicated value (dosimetry system)

For the type test according to this standard, 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 it is not designed for, for example 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 software after the type test shall be prevented.

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 only in case the dosimetry system is used for official purposes, for example, legally relevant personal monitoring.

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

Testing of 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 the reader or dosemeter is operated with software other than the type tested.

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. 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 standard 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.

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.

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, 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, 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, at least CRC-16 with a secret start value hidden in the executable file. The software reads the data set, calculates the checksum 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 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, 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. 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 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.

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, 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 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. Secret data (for example key initial value if used) shall be kept secret against spying out with simple tools. 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 interface as keyboard, software interfaces) 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 3.15.

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 can be applied which has to be the same for both photon and beta radiation. Thus, the reference radiation quality has to 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 Tables 8 to 12.

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 Tables 8 to 12 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. In case the dosemeter has got separate detectors for photon and beta radiation, the test shall be performed with a beta source, too, for example ^{90}Sr/^{90}Y. During the tests, the dosemeter shall be irradiated on the required phantom (see 5.1.5) from the reference direction.

NOTE 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.

b) Tests to be performed

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

The response shall be measured for at least three dose values in each order of magnitude of the measuring range. These shall be at approximately 20 %, 40 % and 80 % of each full order of magnitude 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.

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 Tables 8 to 12 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 Tables 8 to 12,

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 Tables 8 to 12 (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 $0{,}91 - U_{C,\mathrm{com}} \leq \left(\frac{\overline{G_i}}{\overline{G}_{r,0}} \pm U_{\mathrm{com}} \right) \cdot \frac{C_{r,0}}{C_i} \leq 1{,}11 + U_{C,\mathrm{com}}$ is valid and

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

U_{com} is calculated according to Equation (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 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 Tables 8 to 12, the indicated value shall not be less than H_{up} and the system shall display 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 standard 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.

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

Group 2: one dosemeter shall be irradiated with a high dose equivalent as given in line 8 of Tables 8 to 12.

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

$0{,}91 - U_{C,\text{com}} \leq \left(\frac{\overline{G_i}}{\overline{G}_{r,0}} \pm U_{\text{com}} \right) \cdot \frac{C_{r,0}}{C_i} \leq 1{,}11 + U_{C,\text{com}}$ 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 Tables 8 to 12, then the requirements of 11.4.1 are considered to be met.

U_{com} is calculated according to Equation (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 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 Tables 8 and 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 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 fall within the rated range of energy	For all radiation qualities whose mean energy fall 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	Three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
90°	This test is given in 11.8	Three lowest energies in rated range of energy
± (180°– α_{max})	No test	As for α_{max}, not necessary if badge is symmetrical
± 105°	No test	As for 75°, not necessary if badge is symmetrical
± 120°	No test	As for 60°, not necessary if badge is symmetrical
180°	No test	As for 0° angle of incidence, not necessary if badge is symmetrical

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.

[C] NOTE Z1 For personal dose quantities: Also take into account section 8.4 f) and line 11 of Table 8. [C]

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.

〖C〗 For $H^*(10)$ dosemeters and α = 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. 〈C〗

For non-symmetrical $H_p(10)$ dosemeters (see Note 1 and 8.4 f)), 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 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 $H_p(10)$ 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 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 Tables 8 and 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 Equation (A.5), Example 2. $U_{C,\text{com}}$ is the combined relative expanded uncertainty of $\frac{C_{\text{r,0}}}{C_i}$: $U_{C,\text{com}} = \sqrt{U_{C,\text{rel;r,0}}^2 + U_{C,\text{rel;}i}^2}$ with the relative expanded uncertainties $U_{C,\text{rel; r,0}}$ and $U_{C,\text{rel;}i}$ of the conventional true 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.

11.5.2 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 Tables 8 and 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 ($\geq$ 4) dosemeters 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 shall be determined.

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

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 Equation (A.3).

11.6 Radiation energy and angle of incidence for $H_p(3)$ 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.

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 for $H_p(3)$ dosemeters

α	$H_p(3)$ dosemeters (irradiations on phantom, see 5.1.5)
0°	For all radiation qualities whose mean energy fall within the rated range of energy
± 60°	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
± α_{max}	Three lowest energies in rated range of energy
90°	This test is given in 11.8

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.

〈C〉 NOTE Z1 Also take into account section 8.4 f) and line 11 of Table 9. 〈C〉

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)), 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 Equation (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 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

〖C〗 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.

Requirement B: As the dosemeter is intended to measure $H_p(3)$, 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). 〖C〗

11.6.2.2 Method of test

〖C〗 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). 〖C〗

〈C〉 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, $H_p(3)$, are available in ISO 6980-3, the values given in Annex G 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 an $H_p(3)$ dosemeter, at each of the two lowest radiation energies, at least five groups of dosemeters are irradiated: one at 0° and four at 60°.

For requrirement B:

For this test, the dosemeter shall be placed on a phantom as required (see 5.1.5). Expose n (≥ 4) dosemeters 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.

NOTE Z1 Details of the reference radiation and the calibration procedure are given in ISO 6980.

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

11.6.2.3 Interpretation of the results

〈C〉 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 Equation (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 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 Equation (A.3). 〈C〉

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 Tables 10 and 12 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 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 fall within the rated range of energy	For all radiation qualities whose mean energy fall 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	Three lowest energies in rated range of energy
± α_{max}	Three lowest energies in rated range of energy	Three lowest energies in rated range of energy
90°	This test is given in 11.8	Three lowest energies in rated range of energy
± (180° − α_{max})	No test	Three lowest energies in rated range of energy
± 105°	No test	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.

[C] NOTE Z1 For personal dose quantities: Also take into account section 8.4 f) and line 11 of Table 10. [C]

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.

[C] 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. [C]

For non-symmetrical $H_p(0,07)$ dosemeters (see Note 1 and 8.4 f)), 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 Tables 10 and 12.

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 Equation (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 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 Tables 10 and 12.

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

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 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 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: $\alpha = 0°$, $\alpha = \pm 45^{\circ}$, as well as $\alpha = \pm 60^{\circ}$ and $\alpha = \pm 75^{\circ}$ 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 Tables 10 and 12.

U_{com} is calculated according to Equation (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 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 〚C〛 Over indication due to radiation incident from the side of an $H_p(10)$, $H_p(3)$ or $H_p(0,07)$ dosemeter 〚C〛

11.8.1 Requirements

〚C〛 If the dosemeter is irradiated free in air from the side (α_{max} to 180°–α_{max}), the indicated value shall not exceed 3 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 Z1 No lower limit is required as the conventional true value is zero for beta radiation and for low energy photon radiation. 〚C〛

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°.

〈C〉 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°.
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 75°, 90°, and 105°. 〈C〉

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

〈C〉 If, for every polar angle examined in accordance with 11.8.2, the inequality $\frac{\overline{G}_{\alpha_{max}\,\text{to}\,180°-\alpha_{max}}}{\overline{G}_{0°}} + U_{com} \leq 3$ is valid, then the requirement of 11.8.1 is considered to be met.

U_{com} is calculated according to Equation (A.5), Example 2. 〈C〉

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, this requirement is fulfilled and no tests are required (the algorithm is an additive one).

If any branching or decision points from which on different methods (or equations or corrections) are used in the algorithm, then 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. The difference in the radiation qualities 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 standard 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 standard, 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 done 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 $f(S_{g,\mathrm{K}})$ calculated using the signals $S_{g,\mathrm{K}}$ 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 $S_{g,\mathrm{K}} + S_{g,\mathrm{L}}$ for each detector element g. From this sum, the indicated value $G_{\mathrm{K+L}} = f(S_{g,\mathrm{K}} + S_{g,\mathrm{L}})$ for the mixed irradiation condition K+L with the conventional true dose value $C_{\mathrm{K+L}} = C_{\mathrm{K}} + C_{\mathrm{L}}$ shall be calculated. The indicated value $G_{\mathrm{K+L}} = f(S_{g,\mathrm{K}} + S_{g,\mathrm{L}})$ 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 $r = \frac{G_{\mathrm{K+L}}}{C_{\mathrm{K+L}}} \cdot \frac{C_{r,0}}{G_{r,0}}$ for every combination described above. In Annex H, 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 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 contributions of different radiation qualities. The combination of each contribution with each other leads to 1 683·1682/2 = 1 415 403 combinations.

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

〚C〛 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. 〚C〛

Three different situations may occur:

a) In case it is not clear whether the influence quantity acts as type S or as type F, the conventional true 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 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 assured, 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 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 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

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

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 13.

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 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 13.

〖C〗 U_{com} is calculated according to Equation (A.5), Example 1 or Example 2, for differences or ratios, respectively. 〖C〗

13.3 Light exposure (dosemeter)

13.3.1 General

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

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 13.

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 13.

〈C〉 U_{com} is calculated according to Equation (A.5), Example 1 or Example 2, for differences or ratios, respectively. 〈C〉

13.4 〈C〉 Dose build-up, fading and self-irradiation (dosemeter) 〈C〉

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

〈C〉 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 13. 〈C〉

13.4.3 Method of test

〈C〉 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 shall 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).

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

Treatment of the three groups after the irradiation:

Group 1 shall be read out 24 hours (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. 〈C〉

13.4.4 Interpretation of the results

〈C〉 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 13.

U_{com} and U_{m} are calculated according to Equation (A.5), Example 1 or Example 2, for differences or ratios, respectively, and Equation (A.3), respectively. 〈C〉

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

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

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 13 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 13.

〈C〉 U_{com} is calculated according to Equation (A.5), Example 1 or Example 2, for differences or ratios, respectively. 〈C〉

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 13.

〈C〉 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. 〈C〉

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.

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

Groups 1 and 2 shall be exposed to $7 \cdot H_{low}$, 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 13.

〈C〉 U_{com} is calculated according to Equation (A.5), Example 1 or Example 2, for differences or ratios, respectively. 〈C〉

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 13.

13.8.3 Method of test

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

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 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 13.

〈C〉 U_{com} is calculated according to Equation (A.5), Example 1 or Example 2, for differences or ratios, respectively. 〈C〉

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 13.

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 13.

〈C〉 U_{com} is calculated according to Equation (A.5), Example 1 or Example 2, for differences or ratios, respectively. 〈C〉

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.

14.2 Requirement

〈C〉 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 14. 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 14 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. 〈C〉

14.3 Method of test

〈C〉 As the tests described in this clause are performed using rather low doses such as $7 \cdot H_{\text{low}}$ 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 14 seven groups of n (≥ 10) dosemeters and for the test according to line 7 of Table 14 one group of n (≥ 13) dosemeters shall be exposed to a reference source with a dose equivalent of $7 \cdot H_{\text{low}}$. For those influence quantities for which a declaration of the manufacturer is available, see 14.2, no dosemeters need to be irradiated. 〈C〉

〈C〉 Group 1, reference group: no electromagnetic influences shall be present. To assure 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 14 prior to their readout. The radio frequency radiation shall be applied with the frequencies stated in footnote d to Table 14.

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 14. 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. 〈C〉

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 Equation (A.5).

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 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 systems 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 $\pm\, 0{,}7 \cdot H_{\text{low}}$ 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

〈C〉 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. 〈C〉

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 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 $\pm$ 10 %. Therefore, by this method of test, it is simultaneously assured, 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 $\pm$ 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 Equation (A.5).

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 standard.

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 standard 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).

〈C〉 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 dose value	Sv
C_i	Conventional true dose value of irradiation group i	Sv
C_K	Conventional true value of (delivered) dose equivalent for irradiation condition K	Sv
C_L	Conventional true value of (delivered) dose equivalent for irradiation condition L	Sv
C_r	Conventional true 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, 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
$f(S_1,\ldots S_b) = f(\vec{S}_g)$	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
$H_p(0,07)$	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

〈C〉

Table 6 *(continued)*

Symbol	Meaning	Unit
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	—
$N_{\max}$	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	—
$r_{\max,\text{w}}$	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	—
$r_{\min,\text{w}}$	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
$S_{g,\text{K}}$	Signal number g due to the radiation quality K	Depending
$S_{g,\text{L}}$	Signal number g due to the radiation quality L	Depending
$t_{\max}$	Maximum rated measurement time	Month
$t_{n\text{-}1}$	Students t-factor for n measurements	—
U	Expanded uncertainty	As quantity
$U_{C,\text{com}}$	Expanded uncertainty of a combined quantity of conventional true 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
$U_{C,\text{rel}}$	Relative expanded uncertainty of the conventional true 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, Equation (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 $H_p(10)$, $H^*(10)$, and $H_p(3)$ $H_p(0,07)$ and $H'(0,07)$	3 mSv 10 mSv	1 mSv to 10 mSv 3 mSv to 30 mSv
Photon radiation energy for $H_p(10)$, $H^*(10)$, $H_p(3)$, $H_p(0,07)$, and $H'(0,07)$	S-Cs (ISO 4037) [a]	S-Cs (ISO 4037) [a]
Beta radiation energy for $H_p(3)$, $H_p(0,07)$, and $H'(0,07)$	$^{90}Sr/^{90}Y$ (ISO 6980) [a,b]	$^{90}Sr/^{90}Y$ (ISO 6980) [a,b]
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 %
A. C. 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 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.

〚C〛 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 10 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)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from 60° to 120°	Indication less than 3 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 13	See Table 13	13
15	Deviation due to electromagnetic performance requirements	See Table 14	See Table 14	14
16	Deviation due to mechanical performance requirements	Drop; for details, see Table 15	± 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]

〚C〛

〈C〉 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 $\leq H < 1{,}1$ mSv $H \geq 1{,}1$ mSv	15 % (18,75 – H/0,08 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 10 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	r_{min} = 0,71 to r_{max} = 1,67	11.6.1
10	Relative response, r, due to mean beta radiation energy	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)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from 60° to 120°	Indication less than 3 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 13	See Table 13	13
15	Deviation due to electromagnetic performance requirements	See Table 14	See Table 14	14
16	Deviation due to mechanical performance requirements	Drop; for details, see Table 15	± 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]

〈C〉

〈C〉 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	–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 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	11.7.1
10	Relative response due to mean beta radiation energy	0,8 MeV and 0° to ± 60° for extremity dosemeters 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 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)
12	Radiation incidence from the side of the dosemeter	Radiation incidence from 60° to 120°	Indication less than 3 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 13	See Table 13	13
16	Deviation due to electromagnetic performance requirements	See Table 14	See Table 14	14
17	Deviation due to mechanical performance requirements	Drop; for details, see Table 15	± 0,7·H_{low} at a dose of H = 7 H_{low}	15

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〈C〉 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 10 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° from reference direction	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 13	See Table 13	13
13	Deviation due to electromagnetic performance requirements	See Table 14	See Table 14	14
14	Deviation due to mechanical performance requirements	Drop; for details, see Table 15	± 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]

〈C〉

[C] Table 12 – 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 ≤ 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 10 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° from reference direction	r_{min} = 0,71 to r_{max} = 1,67 and r_{min} = 0,67 to r_{max} = 2,00	11.7.1
10	Relative response due to mean beta radiation energy	0,2 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 13	See Table 13	13
13	Deviation due to electromagnetic performance requirements	See Table 14	See Table 14	14
14	Deviation due to mechanical performance requirements	Drop; for details, see Table 15	± 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]				

[C]

〈C〉 Table 13 – 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/ Subclause
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 H_{low} at a dose of H = 11 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 Tables 8 to 12	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 Tables 8 to 12	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 Tables 8 to 12	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 Tables 8 to 12	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.

〈C〉

〈C〉 Table 14 – 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 kV to ± 8 kV air discharge 0 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 kV to ± 2 kV (a.c. power ports, line-to-earth) 0 kV to ± 1 kV (a.c. power ports, line-to-line) 0 kV to ± 0,5 kV (d.c. power ports) 0 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)	A	IEC 61000-4-3 Frequencies stated in note [d]	± 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] Frequencies for the Radio-frequency test:
98 / 202 / 550 / 710 / 873 / 903 / 947 / 1472 / 1800 / 1890 / 2035 / 2150 / 2450 MHz.

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Table 15 – 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

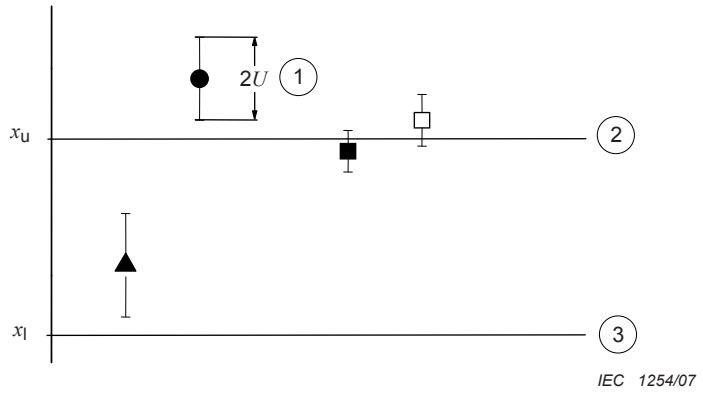
Annex A
(normative)

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, 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:

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

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, Equation 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
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 Equation (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 $\overline{x}$ is described in the ISO/IEC Guide 98-3:2008, Annex G.4.1. Nevertheless, for the purpose of this standard, Equation (A.5) can be used as a good approximation. The following examples use Equation (A.5).

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

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

EXAMPLE 2 $\overline{x} = \dfrac{\overline{G}_1}{\overline{G}_{\text{r,0}}}$ 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 Equation (A.3).

Suppose group 1 of n = 10 dosemeters was irradiated to a conventional true 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 equation (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 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.

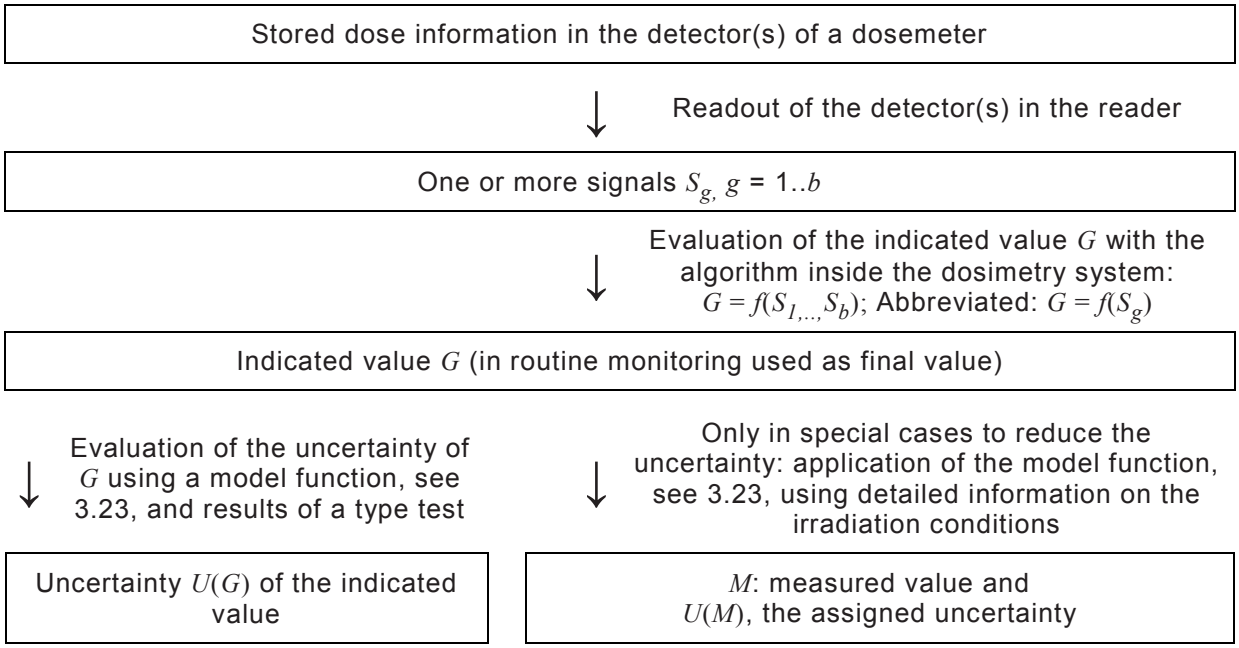
In conclusion, the inequation $0{,}91 - U_{C,\text{com}} \le \left(\dfrac{\overline{G}_i}{\overline{G}_{\text{r,0}}} \pm U_{\text{com}}\right) \cdot \dfrac{C_{\text{r,0}}}{C_i} \le 1{,}11 + U_{C,\text{com}}$ becomes

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 3.38), indicated value (see 3.13) and the measured value (see 3.20) is shown in the following Figure B.1.



IEC 1255/07

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 detector sensitivity factor 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. 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 3.23) and further information, for example results of a type test according to this standard.

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 3.23). 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 standard

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

〈C〉 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	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 H	Mostly 0 / 0 Maybe 3 / 12	12
14		Perform irradiations and additional influences, for example storing of three groups for a time of t_{max}	21/126	13
15		Perform irradiations and additional influences	8 / 83	14
16		Perform irradiations and additional influences	4 / 24	15

〈C〉

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** (environ-ment)	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
(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 $\sqrt{\sum_{13.2\,\text{to}\,13.9} (\frac{1}{r_q} - 1)^2} \leq 20\ \%$ 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.

〚C〛 NOTE Z1 Further details regarding the model function and the determination of uncertainty in measurement are given in IEC/TR 62461. 〈C〉

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 H
(informative)

Computational method of test for mixed irradiations

In Figure H.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".

〈C〉 An example of a dosemeter signal table is given in Table H.1.

Table H.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	…	…	…	…

〈C〉

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 $r_{max,w} = \frac{r_{max,K} \cdot i + r_{max,L} \cdot (10 - i)}{10}$.

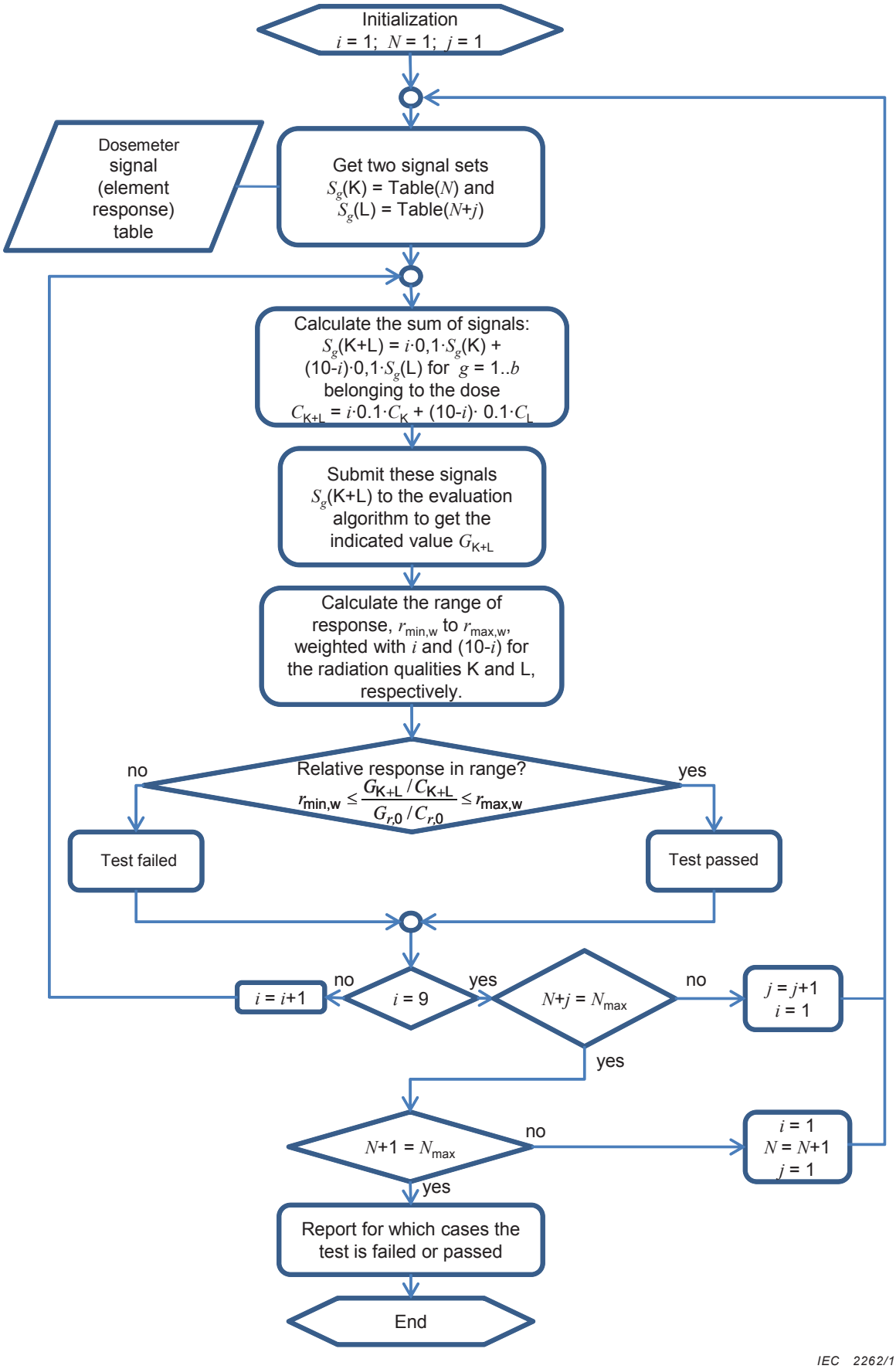


Figure H.1 – Flow chart of a computer program to perform tests according to 12.2

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