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Radiological protection — Criteria and performance limits for the periodic evaluation of dosimetry services for external radiation

Radioprotection — Critères et limites de performance pour l'évaluation périodique des services de dosimétrie pour le rayonnement externe

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 430, *Nuclear energy, nuclear technologies, and radiological protection,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 14146:2018) which has been technically revised.

The main changes are as follows:

— the addition and clarification of several definitions;

— the modification of the requirements to environmental dosemeters;

— the addition of a requirement at reference conditions.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Radiological protection — Criteria and performance limits for the periodic evaluation of dosimetry services for external radiation

1 Scope

This document specifies the dosimetric and organizational criteria and the test procedures to be used for the periodic verification of the performance of dosimetry services supplying personal and/or area, i.e. workplace and/or environmental, dosemeters used for individual (personal) and/or area, i.e. workplace and/or environmental monitoring.

NOTE The quality of a supplier of a dosimetry service depends on both the characteristics of the approved (type-tested) dosimetry system[1)] and the training and experience of the staff, together with the calibration procedures and quality assurance programmes.

The performance evaluation according to this document can be carried out by a dosimetry service to demonstrate the fulfilment of specified performance requirements. The irradiation qualities used in this document are representative for exposure situations that are expected or mimic workplace fields from the radiological activities being monitored using the dosemeters from the services.

This document applies to personal and area dosemeters for the assessment of external photon radiation with a fluence-weighted mean energy between 8 keV and 10 MeV, beta radiation with a fluence-weighted mean energy between 60 keV and 1,2 MeV, and neutron radiation with a fluence-weighted mean energy between 25,3 meV, i.e. thermal neutrons with a Maxwellian energy distribution with kT = 25,3 meV, and 200 MeV.

It covers all types of personal and area dosemeters needing laboratory processing (e.g. thermoluminescent, optically stimulated luminescence, radiophotoluminescent, track detectors or photographic-film dosemeters) and involving continuous measurements or measurements repeated regularly at fixed time intervals (e.g. several weeks, one month).

Active direct reading as well as semi-passive or hybrid dosemeters, such as direct ion storage (DIS) or silicon photomultiplier (SiPM) dosemeters, for dose measurement, can also be treated according to this document. Then, they are treated as if they were passive, i.e. the dosimetry service reads their indicated values and reports them to the evaluation organization.

In this document, the corrected indicated (corrected indication) value is the one given by the dosimetry systems as the final result of the evaluation algorithm (for example display of the software, printout) in units of dose equivalent (Sv).

Environmental dosemeters usually indicate the quantity $H^*(10)$ but they can, in addition or alternatively, indicate the quantity $H'(3)$, $H'(0{,}07)$, air kerma, K_a, or absorbed dose, D. All these dosemeters can also be treated according to this document. If K_a or D is indicated (in Gy) the dose values in this document stated in Sv shall then be interpreted as equivalent values in Gy.

1) If this document is applied to a dosimetry system for which no approval (pattern or type test) has been provided, then in the following text approval or type test should be read as the technical data sheet provided by the manufacturer or as the data sheet required by the regulatory body.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4037-1, *Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods*

ISO 4037-2, *Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 2: Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV*

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

ISO 6980-1, *Nuclear energy — Reference beta-particle radiation — Part 1: Methods of production*

ISO 6980-2, *Nuclear energy — Reference beta-particle radiation — Part 2: Calibration fundamentals related to basic quantities characterizing the radiation field*

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

ISO 8529-1, *Neutron reference radiations fields — Part 1: Characteristics and methods of production*

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

ISO 8529-3, *Neutron reference radiation fields — Part 3: Calibration of area and personal dosemeters and determination of their response as a function of neutron energy and angle of incidence*

ISO 12749-2, *Nuclear energy, nuclear technologies, and radiological protection — Vocabulary — Part 2: Radiological protection*

ISO 12789-1, *Reference radiation fields — Simulated workplace neutron fields — Part 1: Characteristics and methods of production*

ISO 12789-2, *Reference radiation fields — Simulated workplace neutron fields — Part 2: Calibration fundamentals related to the basic quantities*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO/TS 18090-1, *Radiological protection — Characteristics of reference pulsed radiation — Part 1: Photon radiation*

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

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

IEC 61267, *Medical diagnostic X-ray equipment — Radiation conditions for use in the determination of characteristics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12749-2, ISO 29661 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
approved dosimetry system
dosimetry system that is used by a dosimetry service that has been approved or authorized for use by the qualification body

Note 1 to entry: Several dosemeter designs can be operated using the same associated processing system (dosemeter reader, etc.). Then, they are regarded as separate dosemeters/dosimetry systems.

3.2
area dosemeter
dosemeter designed to measure the ambient dose equivalent (rate) or the directional dose equivalent (rate)

Note 1 to entry: For a general definition of dosemeter, see 3.7.

Note 2 to entry: Area dosemeters are used for area monitoring which comprises environmental and workplace monitoring, see 3.3.

[SOURCE: ISO 29661:2012, 3.1.2, modified — Notes 1 and 2 added.]

3.3
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 usually performed in terms of $H'(0,07)$, $H'(3)$ or $H^*(10)$.

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

[SOURCE: IEC 62387:2020, 3.46]

3.4
background dose
radiation dose
dose (or an observed measure related to the dose) attributable to all sources other than the one(s) specified

Note 1 to entry: Strictly, this applies to measurements of dose or counts from a sample, where the background dose or counts must be considered (usually subtracted) from all measurements. However, background is used more generally to refer to the effects of other sources in any situation in which a particular source (or group of sources) is under consideration. It is also applied to quantities other than doses, such as activity concentrations in environmental media.

Note 2 to entry: The background dose can contain dose fractions from transportation and/or other events such as X-ray screening for security checks.

Note 3 to entry: To determine the background dose, usually, a group of control (background) dosemeters is used.

[SOURCE: IAEA Safety Glossary 2022, modified: “dose” and “(radiation dose)” added to the term; “dose rate” removed; second sentence in note 1 rearranged; notes 2 and 3 added]

3.5
control dosemeter
personal, area or environmental dosemeter that provides an estimate of any radiation dose received by the evaluation sample apart from that given by the irradiation laboratory or by a controlled exposure to environmental radiation

Note 1 to entry: The control dosemeter provides a means of estimating and eliminating the contribution to the dose from natural background radiation and that received during the time between zeroing and read out, i.e. the dose during handling, transportation, etc.

Note 2 to entry: The control dosemeters are used to determine the background radiation dose.

3.6
corrected indication
corrected indicated value
G_{corr}
indication of a dosemeter corrected for any differences of the values of the influence quantities from reference conditions

Note 1 to entry: The corrected indication G_{corr} can be calculated with the correction factor k_n for non-constant response, the q correction factors, k_f, for the influence quantities of type F and the p correction summands, G_w, for the influence quantities of type S. It is given by

$$G_{corr} = k_n \cdot (G - \sum_{w=1}^{p} G_w) \cdot \prod_{f=1}^{q} k_f$$

The equation above is a model function of the measurement necessary for any determination of the uncertainty according to the ISO/IEC Guide 98-3 (GUM).

Note 2 to entry: Some *dosimetry systems* (3.9), especially such for neutron radiation, can have different correction factors (or functions) k_w for different workplace categories w, each with its own reference radiation quality (e.g. ^{252}Cf(bare) for one workplace category and ^{252}Cf(D_2O moderated) for another workplace category). Then, to obtain the correspondingly corrected indicated dose value G_{corr}, the uncorrected indicated values G, needs to be multiplied by $k_w \neq 1$: $G_{corr} = G \cdot k_w$. Further information on the use of different correction factors (or functions) for different workplace categories can be found in ISO 21909-2[2]. In ISO 21909-2, the symbol for the correction factor (or function) is $k_{n,E,\Omega}$ instead of k_w.

[SOURCE: ISO 29661:2012, 3.1.11, modified — term “corrected indicated value” added and original Note 2 deleted and new Note 2 to entry added.]

3.7
dosemeter
device having a reproducible, measurable response to radiation that can be used to measure absorbed dose (in Gy) or personal, ambient or directional dose equivalent (in Sv)

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 and software to evaluate and display the indicated value of the absorbed dose or dose equivalent.

Note 3 to entry: For specific types of dosemeters, see 3.2, 3.10, 3.17 and 3.25.

[SOURCE: ISO 12749-2:2022, 3.4.12, modified — “(in Gy)”, “(in Sv)” and “ambient or directional” added and Notes 1 and 2 to entry added]

3.8
dosimetry service
organization that operates a personal, area and/or environmental dosimetry system which includes the evaluation of the reading of dosemeters after their use and includes:

— providing the user with dosemeters;

— recording the results;

— reporting the results to the user.

Note 1 to entry: The dosimetry service fulfils basic quality management and independency requirements if it fulfils the requirements stated in ISO/IEC 17025.

Note 2 to entry: The user includes not only external clients but also internal personnel who wear dosemeters provided by their own organization and are engaged in radiation protection activities inside or outside the organization. The same quality of dosimetry service which is provided to external users is also provided to organizations' employees (internal users), in accordance with their own quality management system.

3.9
dosimetry system
dosemeter, reader and all associated equipment and procedures including software used for assessing and visualizing the indicated value

[SOURCE: IEC 62387:2020, 3.12, modified — "including software" and "and visualizing" added]

3.10
environmental dosemeter
dosemeter used for environmental monitoring

Note 1 to entry: For a general definition of *environmental monitoring*, see 3.11.

Note 2 to entry: Environmental dosemeters are typically used in areas of the environment close to or inside an installation emitting ionizing radiations such as nuclear installations or medical accelerators. In these areas usually no occupationally exposed person is present.

Note 3 to entry: Environmental dosemeters are generally used for monitoring the dose limits of the general population, which are significantly lower as for occupationally exposed individuals. Consequently, the requirements for environmental dosemeters are stronger than for workplace dosemeters, especially the lower dose limit of 35 µSv and the extended range for the angle of incidence of the incident radiation ranging from 0° up to ±75°.

3.11
environmental monitoring
area monitoring (3.3) by the measurement of external dose (rate) in the environment

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

[SOURCE: IEC 62387:2020, 3.48]

3.12
evaluation sample
randomly selected representative group of personal, area or environmental dosemeters used to evaluate the performance of a *dosimetry service* (3.8)

Note 1 to entry: The evaluation sample includes dosemeters that are irradiated, remain unirradiated or serve as control dosemeters for the evaluation procedure.

3.13
evaluation organization
impartial organization that administers the performance evaluation of *dosimetry services* (3.8) and assesses the results

Note 1 to entry: The evaluation organization may include the irradiation laboratory.

Note 2 to entry: The evaluation organization fulfils basic quality management and independency requirements if it fulfils the requirements stated in ISO/IEC 17043.

3.14
irradiation laboratory
impartial laboratory possessing radiation sources, calibration equipment and associated facilities traceable to national, i.e. to primary or secondary, standards able to irradiate dosemeters from the evaluation sample to a high degree of metrological accuracy

Note 1 to entry: The irradiation laboratory fulfils basic quality management and independency requirements if it fulfils the requirements stated in ISO/IEC 17025 for calibration laboratories. Accreditation according to ISO/IEC 17025 impartially confirms the competence of the irradiation laboratory.

3.15
indication
indicated value
G
quantity value provided by a measuring instrument or a measuring system

Note 1 to entry: The units of the indication of the dosemeter are not necessarily the same as that of the measurand. For example, for measurements with ionization chambers the instrument indication is, in general, the value of the current I or of the charge Q. It is necessary to document whether the indication is normalized to the reference conditions to account for influence quantities and is corrected for intrinsic background and other influences. The corrected indication is named G_{corr}.

Note 2 to entry: It may be necessary that a measured dose (e.g. by control dosemeters) or a transport and/or background dose determined by other means be considered (usually subtracted) by the *dosimetry service* (3.8) or by the evaluating organization, see notes to the definition of 3.18, *irradiated dose*.

Note 3 to entry: This definition means the same as "indicated value" in IEC 62387:2020, 3.14.

[SOURCE: ISO 29661:2012, 3.1.15, modified — term "indicated value" added and original Notes 1 and 3 deleted and new Notes 2 and 3 to entry added]

3.16
personal dosemeter
dosemeter used for individual (personal) monitoring

Note 1 to entry: For a general definition of *dosemeter*, see 3.7.

Note 2 to entry: Depending on the wearing position and type of construction a personal dosemeter may be a whole-body dosemeter, an eye lens dosemeter or and extremity dosemeter.

Note 3 to entry: Personal dosemeters are used for *individual monitoring*, see 3.17.

3.17
individual monitoring
monitoring using dose (rate) measurements by equipment worn by individual workers

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: IEC 62387:2020, 3.49, modified — ", or measurements of quantities of radioactive material in or on their bodies" deleted in the end]

3.18
irradiated dose
H_{ref}
conventional quantity value of the dose to which the *dosemeter* (3.7) is irradiated

Note 1 to entry: In most cases, H_{ref} is a dose irradiated by a calibration laboratory using artificial radiation sources (such as radionuclide sources, X-ray tubes or others) in addition to the background dose and, consequently, the background dose must be considered (usually subtracted) to calculate the corrected indicated dose value G_{corr}.

Note 2 to entry: Especially for environmental dosemeters, H_{ref} can include or be identical to a dose received from a controlled exposure to natural environmental radiation. In these cases, it is not considered (usually subtracted) to calculate the corrected indicated dose value G_{corr}. The conventional quantity value for natural environmental radiation can be assessed as described in the literature[3].

3.19
lower dose limit
H_0
dose below which irradiations should not be performed

3.20
natural background dose
H_{nat}
doses or activity concentrations associated with natural sources or any other sources in the environment that are not amenable to control

Note 1 to entry: This is normally considered to include doses or activity concentrations associated with natural sources, global fallout (but not local fallout) from atmospheric nuclear weapon tests.

[SOURCE: IAEA Safety Glossary 2022, modified: "(radiation dose)" added to the term; "dose rate" removed]

3.21
qualification body
impartial organization empowered by a governmental, regulatory or advisory agency to approve a *dosimetry service* (3.8) or authorize the use of a *dosimetry system* (3.9)

Note 1 to entry: The qualification body may include the *evaluation organization* (see 3.13).

Note 2 to entry: The qualification body fulfils basic quality management and independency requirements if it fulfils the requirements stated in ISO/IEC 17025.

3.22
reference condition
operating condition prescribed for evaluating the performance of a measuring instrument or measuring system or for comparison of measurement results

Note 1 to entry: Reference operating conditions specify intervals of values of the measurand and of the influence quantities.

[SOURCE: JCGM. International vocabulary of metrology – Basic and general concepts and associated terms (VIM). 3rd Ed. JCGM 200, 2012. p. 108]

Note 2 to entry: The term "reference condition" refers to an operating condition under which the specified instrumental measurement uncertainty is the smallest possible.

[SOURCE: IEC 60050-300, 311-06-02]

Note 3 to entry: Reference conditions usually represent the set of influence quantities for which the calibration factor is valid without any correction.

Note 4 to entry: The reference conditions for the quantity to be measured may be chosen freely in agreement with the properties of the instrument under test. The quantity to be measured is not an influence quantity.

3.23
response
quotient of the indication, G, or of the corrected indication, G_{corr}, divided by the conventional quantity value to be measured.

Note 1 to entry: The full specification of the response includes specification of whether it is determined from G or G_{corr} and a statement of the measuring quantity. Examples are the response of the response of the corrected indication with respect to the absorbed dose, R_D, and the response of the corrected indication with respect to the operational quantity $H_p(10)$, $R_{Hp(10)}$.

Note 2 to entry: The reciprocal of the response at reference conditions is equal to the calibration coefficient.

Note 3 to entry: The value of the response may vary with the magnitude of the quantity to be measured (dose). In such cases the response is said to be non-constant (or the indication is nonlinear).

Note 4 to entry: The response usually varies with the energy and directional distribution of the incident radiation. Therefore, it may be useful to give the response as table of single values or diagram or curve or function $R(\bar{E},\Omega)$ of the mean radiation energy $\bar{E}$ of the radiation quality and the direction Ω of the incident monodirectional radiation. $R(\bar{E})$ describes the "energy dependence" and $R(\Omega)$ the "angular dependence" of the response; for the latter Ω may be expressed by the angle, α, between the reference direction of the dosemeter and the direction of an external monodirectional field.

Note 5 to entry: For the determination of the photon energy dependence the most accurate information is obtained experimentally if narrow spectra are used (e.g. for X-rays the radiation qualities of the N series as described in ISO 4037-1).

[SOURCE: ISO 29661:2012, 3.1.34; "dose rate" removed; in Note 1 "the corrected indication with respect to fluence, R_{Φ}, the response of the non-corrected indication with respect to kerma, R_K," deleted and Note 1 extended by an example for $H_p(10)$; Note 5: "photon" added and "small spectra" changed to "narrow spectra"]

3.24
upper dose limit
H_{top}
dose above which irradiations should not be performed

3.25
workplace dosemeter
dosemeter used for workplace monitoring

Note 1 to entry: For a general definition of *workplace monitoring*, see 3.26.

Note 2 to entry: Workplace dosemeters are typically used in areas where usually occupationally exposed persons are present.

3.26
workplace monitoring
area monitoring (3.3) using dose (rate) measurements made in the working environment

Note 1 to entry: Usually contrasted with *individual monitoring* (3.17).

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

[SOURCE: IEC 62387:2020, 3.47]

4 Quantities measured

The quantities measured in the evaluation shall be the personal dose equivalent $H_p(10)$, $H_p(3)$ or $H_p(0,07)$, the ambient dose equivalent $H^*(10)$ or the directional dose equivalent $H'(3)$ or $H'(0,07)$ as recommended by the ICRU in Report 47[4] and Report 51[5]. All irradiations for $H_p(d)$ shall be performed on ISO phantoms in accordance with the standard test conditions in Table A.1 of Annex A. When these phantoms are used, no correction factors shall be applied to the indication of the dosemeter under test due to possible differences in backscatter properties between these phantoms and the ICRU tissue phantoms.

5 Frequency of evaluation

As a general rule, performance evaluations should be repeated at regular intervals (e.g. every one or two years), see ISO/IEC 17025:2017, 7.7. If any significant change of the dosimetry system or the dosimetry service occurs after an evaluation which may change the performance of the dosimetry service and/or dosimetry system, performing a new evaluation shall be considered. To maintain compliance with this document for a specific dosimetry system, performance evaluations should be repeated regularly, at best every three years. If a performance test is not provided within this period, four years are recommended, however, at maximum five years is acceptable.

For approved dosimetry systems in countries where applicable, the qualification body shall be notified of the results of the evaluations and of any significant change of the dosimetry service and/or in the dosimetry system after approval. The qualification body shall recommend a new evaluation when it believes that the modifications may change the performance of the dosimetry service and/or dosimetry system.

6 Test conditions

6.1 Standard test conditions and special handling conditions

The dosimetry service shall supply complete dosemeter badges or holders, i.e. complete dosemeter package as it would be worn by a monitored individual or posted as a workplace or environmental dosemeter. A badge or holder consists of the radiation detector(s), possible supplemental filtering materials, labelling and/or identification typically placed within an enclosure suitable for the conditions where it is used and equipped with a means to attach the enclosure to the wearer or within the workplace/environment (e.g. a clip).

The dosimetry service shall

— clearly indicate the front face of the dosemeters, i.e. the face which shall face the radiation source,

— specify the reference point of the dosemeters, and

— provide information on the position (depth) of the sensitive element in the dosemeters.

Environmental dosemeters shall be waterproof.

According to an addition to 6.6.3 in ISO 29661:2012/Amd.1:2015, the reference point of a personal dosemeter can be defined as the rear side of the dosemeter so that it coincides with a point on the front surface of the phantom. Thus, the irradiation laboratory may choose the point of test at the dosemeter's reference points or, in case of personal dosemeters, the phantom front – as appropriate (see ISO 29661:2012/Amd.1:2015).

The dosimetry service shall not be aware of the radiation qualities and doses used for the irradiations.

One or more dosemeter can be irradiated per irradiation condition.

NOTE 1 One good practice for the irradiation laboratory is that different participants' systems are irradiated at the same time, i.e. using the same setup and/or simultaneously on the phantom. This enables cross checking in case of potential irradiation errors.

In case several dosemeters are irradiated simultaneously, 6.6.5 of ISO 29661:2012 shall be obeyed.

Those quantities which may influence the result, such as ambient temperature, relative humidity, background radiation and radioactive contamination, as well as further influence quantities not intended to be varied shall conform to the standard test conditions as given in Annex A.

During the performance evaluation cycle, the evaluation sample, including the control dosemeters, shall be stored in environmental conditions that do not affect the measurement results obtained from the dosemeters. Alternative storage conditions may be used in order to mimic real conditions, especially for environmental dosemeters.

For an accurate consideration (usually subtraction) of the background radiation dose from the readings of the test dosemeters, the amount of time that the controls and test dosemeters are separated, i.e. the time that it takes to perform the tests, shall be minimized. Ideally, the difference between the accumulated control background and the natural background of the test dosemeters should be less than 0,01 mSv, or as small as possible. In any case, it shall be smaller than half of the lower dose limit.

If more than one irradiation laboratory performs the irradiations, sufficient control dosemeters must be provided by the dosimetry service in order to make sure that each group of dosemeters is accompanied by sufficient control and spare dosemeters, see 8.1.

6.2 Radiation qualities

The radiation sources shall be chosen from those specified in ISO 4037-1 (reference photon radiation fields), ISO 6980-1 (reference beta radiation fields), ISO 8529-1 (reference neutron radiation fields), ISO 12789-1 [simulated workplace fields with broad energy and angle distributions (e.g. isotropic)], or IEC 61267 (medical diagnostic radiation fields) according to those radiation types for which the system has been approved. In order to mimic real workplace conditions, other radiation fields may be used if qualified reference dose

measurements are performed. Mixtures may also be used. Pulsed reference photon radiation fields shall be chosen from those specified in ISO/TS 18090-1 or other specified radiation fields.

Additional reference fields of natural environmental radiation may be chosen, especially to evaluate environmental dosemeters. As for all other irradiations, the conventional quantity value from the environmental radiation, H_{ref}, and its uncertainty need to be assessed.

NOTE 1 The conventional quantity value for natural environmental radiation can be assessed as described in the literature[3].

NOTE 2 Conversion coefficients from air kerma to the operational quantities for medical diagnostic radiation fields according to IEC 61267 can be determined as described in the literature[6]. Selected values can be found in the literature[7][8][9].

The choice of radiation qualities and angles of incidence should be guided by the following considerations:

— attempts should be made to vary the radiation qualities used for repeated performance evaluations of the same dosimetry system or the same dosimetry service;

— one radiation quality (preferably the reference radiation quality at reference dose and further reference conditions according to Annex A) should be left unchanged for repeated performance evaluations of the same dosimetry system or the same dosimetry service to assess the calibration control;

— the radiation qualities and angles of incidence should be selected from the range of energies and angles of incidence for which all dosimetry systems taking part in the evaluation have been approved;

— the majority of radiation qualities and angles of incidence should be similar to the conditions found in routine radiation surveillance in order to prevent evaluations from emphasizing performance under extreme conditions.

Radiation qualities with broad energy spectra (e.g. the photon "wide spectrum" series and the photon "high air kerma rate" series) can be used only when their spectra ensure that most of the radiation (at least 90 % fluence weighted) is within the range of energies for which the system — or, if several dosimetry systems take part in the evaluation, for which the majority of the dosimetry systems — has been approved.

Mixtures of two or more radiation qualities may be appropriate in order to mimic workplace fields [e.g. two different energies and/or angles of incidence of the same radiation type, or different radiation types, (e.g. beta and photon radiation or photon and neutron radiation)].

6.3 Dose range

Testing shall be consistent with the dose range for which all dosimetry systems taking part in the evaluation have been approved. The choice of the dose values, H_{ref}, should be guided by the following considerations:

— attempts should be made to vary the dose values used for repeated performance evaluations of the same dosimetry system or the same dosimetry service;

— the majority of irradiated doses should be similar to the conditions found in routine radiation surveillance in order to prevent evaluations from emphasizing performance under extreme conditions;

— the dose values should not be less than the following lower dose limits H_0:

  — 35 µSv for environmental dosemeters measuring $H^*(10)$;

  — 0,1 mSv for workplace dosemeters measuring $H^*(10)$ and for whole-body dosemeters measuring $H_p(10)$ and for whole-body dosemeters measuring both, $H_p(10)$ and $H_p(0,07)$;

  — 0,3 mSv for eye lens dosemeters measuring $H_p(3)$ and for area dosemeters measuring $H'(3)$;

  — 1 mSv for extremity dosemeters measuring $H_p(0,07)$ and for area dosemeters measuring $H'(0,07)$.

NOTE 1 It is recommended to use at least values of H_{ref} larger than three times the expected background dose. According to definition 3.4 and definition 3.5, the background dose does not contain the contribution due to an intended controlled exposure to natural environmental radiation.

NOTE 2 Eye lens dosemeters usually are small resulting in small detectors (as they are worn near the eye). Therefore, H_0 for $H_p(3)$ and $H'(3)$ cannot be as small as H_0 for $H_p(10)$ and $H^*(10)$. Further information on eye lens dosimetry can be found in ISO 15382[10].

— the dose values should not exceed the upper dose limit H_{top} = 10 Sv for area and personal dosemeters.

6.4 Irradiation of dosemeters

The irradiation laboratories shall perform the basic dosimetry according to ISO 4037-2, ISO 6980-2, ISO 8529-2, ISO 12789-2, or IEC 61267, i.e. for photon radiation, beta radiation, neutron radiation, simulated neutron workplace fields or medical diagnostic radiation fields, respectively.

The irradiation laboratories shall perform the irradiations according to ISO 4037-3, ISO 6980-3, ISO 8529-3, ISO 12789-2, or IEC 61267, i.e. for photon radiation, beta radiation, neutron radiation, simulated neutron workplace fields or medical diagnostic radiation fields, respectively.

The uncertainty of the irradiated dose shall be determined in accordance to ISO/IEC Guide 98-3 (GUM) and shall be, in orientation to ICRP 75[11], less than 8 % for a 95 % coverage interval. In simulated workplace fields, for neutron irradiations and in reference fields of natural environmental radiation, the uncertainty can be higher but should not be larger than 15 %. If it were larger, it should be considered in Formula 2 to Formula 4.

7 Performance limits

7.1 Limits to the response

7.1.1 General requirements

For each irradiated dosemeter, the quotient of the corrected indicated dose value G_{corr} and the conventional quantity value H_{ref}, given by Formula (1)

$$R = \frac{G_{corr}}{H_{ref}} \tag{1}$$

shall meet the following criteria between H_0 and H_{top} (see 6.3):

— Criterion 1) For photon radiation with a mean energy of $\bar{E}_{ph}$ > 10 keV, for beta radiation with a mean energy of $\bar{E}_{beta}$ > 0,2 MeV and for neutron radiation for the quantity $H^*(10)$:

$$0{,}71 \cdot \left(1 - \frac{2 \cdot H_0 / 2{,}46}{H_0 / 2{,}46 + H_{ref}}\right) \leq R \leq 1{,}67 \cdot \left(1 + \frac{H_0}{1{,}65 \cdot H_0 + H_{ref}}\right) \tag{2}$$

— Criterion 2) For photon radiation with a mean energy of $\bar{E}_{ph}$ ≤ 10 keV, for beta radiation with a mean energy of $\bar{E}_{beta}$ ≤ 0,2 MeV and for neutron radiation for the quantity $H_p(10)$:

$$0{,}5 \cdot \left(1 - \frac{2 \cdot H_0 / 4{,}0}{H_0 / 4{,}0 + H_{ref}}\right) \leq R \leq 2 \cdot \left(1 + \frac{H_0}{5{,}66 \cdot H_0 + H_{ref}}\right) \tag{3}$$

NOTE 1 According to 6.3, for whole-body dosemeters measuring both, $H_p(10)$ and $H_p(0{,}07)$, a lower limit of H_0 = 0,1 mSv is valid for its $H_p(10)$-indication while a lower limit of H_0 = 1 mSv is valid for its $H_p(0{,}07)$-indication.

If whole-body dosemeters measuring both $H_p(10)$ and $H_p(0{,}07)$ are irradiated with H_{ref} between 0,1 mSv and 1 mSv, for its $H_p(0{,}07)$-indication, the response limits that are valid for 1 mSv shall be applied down to 0,1 mSv.

If mixtures of two or more radiation qualities and or types are used and the above-mentioned harder-to-measure components contribute 20 % or more of the total dose, criterion (2) applies to total dose. Criterion (1) applies for a contribution below 20 %.

NOTE 2 The factors 0,71 and 1,67 (criterion 1) and 0,5 and 2 (criterion 2) limit the maximum deviation of the dosimetry system at high dose values. At the lower limit of the dose range, –70 % and +130 % deviation is allowed.

NOTE 3 The factors 0,71 and 1,67 are similar to the corresponding factors in ICRP 75[11] (0,67 and 1,5).

NOTE 4 Annex B provides graphical illustrations of the performance limits.

NOTE 5 For beta radiation, criterion 2 is valid for Pm-147 radiation. Beta mean energies are given by Behrens[12].

NOTE 6 The criteria are orientated in order to make sure that approved dosimetry systems also pass tests according to this document.

7.1.2 Requirements at reference conditions

For reference conditions of the dosemeter as stated in Annex A, for each irradiated dosemeter, the quotient of the corrected indicated dose value G_{corr} and the conventional quantity value H_{ref} as given by Formula (1), shall meet the following criterion at the reference dose according to Annex A, $H_{ref,0}$:

$$0,8 \leq R \leq 1,25 \tag{4}$$

For other radiation qualities, the limits of 7.1.1 apply.

For dosemeters without a dedicated reference radiation quality (e.g. some dosemeters according to ISO 21909-2[2] such as albedo neutron dosemeters) the calibration should be tested by other methods.

7.2 Approval criterion

The criteria stated in 7.1 are valid for a coverage interval with a coverage probability of 95 %. A maximum of one-tenth of the dosemeters irradiated may exceed the limits.

NOTE 1 A coverage probability of 95 % corresponds to one-twenties. With this, the uncertainty of the delivered dose (see last sentence of 6.3) is taken into account.

NOTE 2 The dosimetry service fulfils basic quality management and impartiality requirements if it fulfils the requirements stated in ISO/IEC 17025 for calibration laboratories.

8 Operational procedures

8.1 Evaluation sample size

The evaluation organization shall specify the number of dosemeters and irradiation conditions for each dosimetry system based on the following considerations:

For each dosimetry system taking part in the evaluation, in total at least 13 dosemeters should be included in the evaluation sample. At least ten dosemeters should be irradiated under at least eight different irradiation conditions from the conditions stated in Clause 6 and at least three dosemeters per irradiation laboratory should be left unirradiated. At least two of them should serve as control dosemeters for the measurement of the sum of the natural background dose and the dose during transport etc. and at least one of them should serve as spare dosemeter in case of failure during the irradiation (e.g. a wrong irradiation) or breakage. One or more dosemeters may be irradiated per irradiation condition.

If the performance evaluation is carried out less frequently than once per year, then the minimum number of irradiated dosemeters should be increased (e.g. by ten more to be irradiated per further year until the next performance evaluation).

8.2 Evaluation procedure

The dosimetry service shall confirm that the dosemeters submitted for evaluation either are representative of those supplied routinely to users or are new dosemeter types not yet routinely used.

The processing of the evaluation dosemeters shall be carried out in exactly the same way as for the dosimetry service's normal customers, i.e. as in routine use, or, for new dosemeter types, in the same way as planned for the future routine use.

To ensure that the processing of the evaluation dosemeters is carried out in exactly the same way as for the dosimetry service's normal customers, the evaluation organization may send a representative to select the dosemeters and to observe that no special effort is made in processing them.

The evaluation organization may obtain the dosemeters and communicate with the dosimetry service through a "dummy customer" and thus prevent the dosimetry service from handling the evaluation sample differently, which could influence the evaluation results.

8.3 Evaluation sequence

Evaluation is normally carried out in the following steps:

a) the dosimetry service orders the evaluation or the evaluation organization initiates the evaluation with or without the dosimetry service's knowledge;

b) the evaluation organization prepares the evaluation schedule, obtains the dosemeters from the dosimetry service and arranges for irradiation of the dosemeters;

c) the evaluation organization provides the information which dosemeters are to be used as control dosemeters; on special request of the dosimetry service the evaluation organization can supply further information on the radiation fields for the correct dose measurement. This can be, for example, a workplace category according to ISO 21909-2 which is of special importance for neutron albedo dosemeters, see Note 2 to entry in definition 3.6;

NOTE 1 Dosemeters not specified as control dosemeters may be left unirradiated as a false positive test, i.e. it is tested whether these dosemeters are recognized as unirradiated by the dosimetry service.

d) the dosimetry service processes the dosemeters using normal practices and reports the measured doses and associated uncertainties to the evaluation organization; the dose shall be reported with three significant digits in order to rule out rounding effects. This may be in contrast to the normal practice; if a dosemeter is faulty this shall be reported and the corresponding dose value (possibly not available as the dosemeter cannot be read out) shall not be considered in the further evaluation;

NOTE 2 Guidance for the determination of the uncertainty of the measured dose can be found in IEC/TR 62461[13].

e) it may be necessary that a measured (e.g. by control dosemeters) or calculated transport and/or natural background dose be considered (usually subtracted) by the dosimetry service or by the evaluation organization. This procedure may be different from routine procedures of dosimetry services. The information about the procedure of the transport and/or natural background dose correction has to be stated by the evaluation organization;

f) if further information on the radiation fields was provided to the dosimetry service (e.g. neutron workplace categories) this extra information shall be included in the test report of the results;

g) the evaluation organization analyses the evaluation results and associated uncertainties and submits them to the dosimetry service and/or qualification body;

h) the evaluation organization maintains the documentation, which shall at least include the following information for each dosemeter:

— a unique identifier for each dosemeter tested;

— the radiation type, energy and the angle of incidence;

— the ambient conditions during the irradiation;

— the phantom used (for personal dosemeters only);

— the values of the delivered dose with associated uncertainties and measured doses with associated uncertainties. The principles used for determining the associated uncertainties should be stated;

— the response *R*.

9 Test report

The qualification body or, if the qualification body is not involved, the evaluation organization shall inform the dosimetry service of the results.

The qualification body or, if the qualification body is not involved, the evaluation organization shall deem competent each dosimetry service which is able to show compliance with the performance limits stated in Clause 7 for each dosimetry system examined.

The qualification body or, if the qualification body is not involved, the evaluation organization shall provide the dosimetry service with a test report which specifies at least

— a reference to the document used, i.e. ISO 14146:2024,

— any deviations from the procedure described in this document,

— any unusual features observed,

— the date of the tests,

— the dosimetry service's name,

— the dosimetry system, quantity and type of radiation for which it has been approved,

— a statement on how the uncertainties of the delivered doses were considered, and

— the information listed in 8.3 h).

Annex A
(normative)

Reference conditions and standard test conditions

Table A.1 — Reference conditions and standard test conditions

Quantity to be measured; influence quantity	Reference conditions (unless otherwise indicated)	Standard test conditions (unless otherwise indicated)
Reference dose equivalent $H_{ref,0}$ for passive dosemeters for		
$H_p(10)$, $H^*(10)$, $H_p(3)$, $H'(3)$:	3 mSv	1 mSv to 10 mSv
$H_p(0,07)$ and $H'(0,07)$:	10 mSv	3 mSv to 30 mSv
Reference dose equivalent $H_{ref,0}$ for active and hybrid dosemeters for		
$H_p(10)$, $H^*(10)$, $H_p(3)$, $H'(3)$:	0,3 mSv	0,1 mSv to 1 mSv
$H_p(0,07)$ and $H'(0,07)$:	1 mSv	0,3 mSv to 3 mSv
For active and hybrid dosemeters: Dose equivalent rate during the irradiations for		
$H_p(10)$, $H^*(10)$, $H_p(3)$, $H'(3)$:	0,3 mSv h^{-1}	0,1 mSv h^{-1} to 1 mSv h^{-1}
$H_p(0,07)$ and $H'(0,07)$:	3 mSv h^{-1}	0,5 mSv h^{-1} to 50 mSv h^{-1}
Neutron radiation quality	^{241}Am-Be (ISO 8529-1)[ab]	^{241}Am-Be (ISO 8529-1)[ab]
Photon radiation quality	S-Cs (ISO 4037-1)[ab]	S-Cs (ISO 4037-1)[ab]
Beta radiation quality	^{90}Sr/^{90}Y (ISO 6980-1)[ab]	^{90}Sr/^{90}Y (ISO 6980-1)[ab]
Angle of radiation incidence	Reference direction	Reference direction ±5°
Ambient temperature	20 °C	15 °C to 25 °C[c]
Relative humidity	65 %	<75 % [c]
Atmospheric pressure	101,3 kPa	86,0 kPa to 106,6 kPa[c]
Radiation background	Ambient dose equivalent rate $\dot{H}^*(10)$ < 0,1 µSv h^{-1} and directional dose equivalent rates $\dot{H}'(0,07;\Omega)$ and $\dot{H}'(3;\Omega)$ < 0,1 µSv h^{-1}	Ambient dose equivalent rate $\dot{H}^*(10)$ < 0,25 µSv h^{-1} and directional dose equivalent rates $\dot{H}'(0,07;\Omega)$ and $\dot{H}'(3;\Omega)$ < 0,25 µSv h^{-1}
Radioactive contamination	Negligible[d]	Negligible[d]

[a] Alternatively, the radiation quality as stated in the approval documentation or manual of the dosemeter or dosimetry system may be chosen; usually a radiation quality where the response is unity, i.e. R = 1,0.

[b] Dosemeters or dosimetry systems intended to measure more than one type of radiation (neutron, photon and/or beta radiation) must have only one reference radiation quality for each detector (signal).

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

[d] Allowable limits on surface contamination are established by local governments. “Negligible” indicates levels of contamination that do not affect the accuracy of the calibration nor pose a risk to the calibration personnel or facility.

[e] For beta radiation, a PMMA slab of at least 20 cm x 20 cm in cross-section and at least 2 cm in thickness may be used to substitute the ISO water-slab or -cylinder phantom.