

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Radiation protection instrumentation – Measurement of personal dose equivalents for X, gamma, neutron and beta radiations – Active personal dosimeters

Instrumentation pour la radioprotection – Mesure des équivalents de dose individuels pour les rayonnements X, gamma, neutron et bêta – Dosimètres individuels actifs



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications, symboles graphiques et le glossaire. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 500 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 25 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Radiation protection instrumentation – Measurement of personal dose equivalents for X, gamma, neutron and beta radiations – Active personal dosimeters

Instrumentation pour la radioprotection – Mesure des équivalents de dose individuels pour les rayonnements X, gamma, neutron et bêta – Dosimètres individuels actifs

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 13.280

ISBN 978-2-8322-8176-5

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	11
3 Terms and definitions	13
4 Units and symbols	21
4.1 Units.....	21
4.2 Symbols.....	21
5 Mechanical characteristics.....	23
5.1 Case.....	23
5.2 Switches	23
6 General characteristics.....	24
6.1 Storage of dose information	24
6.2 Indication	24
6.3 Dosimeter markings	24
6.4 Retention of radioactive contamination.....	24
6.5 Ranges for dose and dose rate	24
6.6 Rated range of an influence quantity.....	24
6.7 Effect of radiation not intended to be measured and use of more than one dosimeter.....	25
6.8 Intrinsic and environmental background of the instrument	25
6.9 Dose or dose rate alarms	25
6.9.1 General	25
6.9.2 Dose alarms	25
6.9.3 Dose rate alarms	25
6.9.4 Alarm output.....	26
6.10 Indication of malfunction	26
6.11 Assignment of the dose value to the dosimeter	26
6.12 Algorithm to evaluate the indicated value	26
7 General test procedures	26
7.1 Nature of tests	26
7.2 Reference conditions and standard test conditions.....	27
7.3 Tests for influence quantities of type F.....	28
7.4 Tests for influence quantities of type S	28
7.5 Phantom for testing.....	28
7.6 Position of detector assembly for the purpose of testing.....	28
7.7 Position of dosimeter during use	28
7.8 Minimum rated range of influence quantity	29
7.9 Low dose rates	29
7.10 Statistical fluctuations	29
7.11 Production of reference radiation	29
8 Additivity of indicated value	29
8.1 Requirements	29
8.2 Method of test.....	30
8.2.1 General	30
8.2.2 Preparation of the test	30

8.2.3	Practical test	31
8.3	Interpretation of the results	31
9	Radiation performance requirements and tests	31
9.1	General.....	31
9.2	Consideration of the uncertainty of the conventional quantity value.....	32
9.3	Constancy of the dose response, dose rate dependence and statistical fluctuations	32
9.3.1	General	32
9.3.2	Requirements	32
9.3.3	Method of test using sources	37
9.3.4	Interpretation of the results of the test using sources.....	38
9.3.5	Method of test for photon dosimeters using natural radiation	39
9.3.6	Interpretation of the results of the test using natural radiation.....	39
9.4	Variation of the response due to photon radiation energy and angle of incidence	40
9.4.1	Measurement quantity $H_p(0,07)$ or $\dot{H}_p(0,07)$	40
9.4.2	Measurement quantity $H_p(3)$ or $\dot{H}_p(3)$	40
9.4.3	Measurement quantity $H_p(10)$ or $\dot{H}_p(10)$	41
9.5	Variation of the response due to neutron radiation energy and angle of incidence	42
9.5.1	General	42
9.5.2	Measurement quantity $H_p(10)$ or $\dot{H}_p(10)$	42
9.6	Variation of the response due to beta radiation energy and angle of incidence	43
9.6.1	General	43
9.6.2	Measurement quantity $H_p(0,07)$ or $\dot{H}_p(0,07)$	43
9.6.3	Measurement quantity $H_p(3)$ or $\dot{H}_p(3)$	44
9.6.4	Measurement quantity $H_p(10)$ or $\dot{H}_p(10)$	45
9.7	Over indication due to radiation incident from the side of an $H_p(10)$, $H_p(3)$ or $H_p(0,07)$ dosimeter	45
9.7.1	Requirements	45
9.7.2	Method of test.....	45
9.7.3	Interpretation of the results	46
9.8	Retention of dose reading	46
9.8.1	General	46
9.8.2	Requirements	46
9.8.3	Method of test and interpretation of the results	46
9.9	Overload characteristics	46
9.9.1	General	46
9.9.2	Requirements	47
9.9.3	Method of test and interpretation of the results	47
9.10	Alarm	48
9.10.1	General	48
9.10.2	Response time for dose rate indication and alarm.....	48
9.10.3	Accuracy of dose alarm	49
9.10.4	Accuracy of dose rate alarm	49
9.11	Model function	50
10	Electrical and environmental performance requirements and tests.....	

10.1	General.....	50
10.2	Power supplies	50
10.2.1	General requirements	50
10.2.2	Specific primary batteries requirements	51
10.2.3	Specific secondary batteries requirements.....	51
10.2.4	Method of test and interpretation of the results (primary and secondary batteries)	51
10.3	Ambient temperature.....	52
10.3.1	Requirements	52
10.3.2	Method of test and interpretation of the results	53
10.4	Relative humidity	54
10.4.1	Requirements	54
10.4.2	Method of test and interpretation of the results	54
10.5	Atmospheric pressure	54
10.6	Sealing	54
10.7	Storage.....	54
10.8	Light exposure	54
10.8.1	General	54
10.8.2	Requirements	55
10.8.3	Interpretation of the results.....	55
10.9	Dose build-up, fading and self-irradiation (hybrid dosimeters)	55
11	Electromagnetic performance requirements and tests	56
11.1	General.....	56
11.2	Electrostatic discharge.....	57
11.2.1	Requirements	57
11.2.2	Method of test and interpretation of the results	57
11.3	Radiated electromagnetic fields	58
11.3.1	Requirements	58
11.3.2	Method of test and interpretation of the results	58
11.4	Conducted disturbances induced by fast transients or bursts	58
11.4.1	Requirements	58
11.4.2	Method of test and interpretation of the results	58
11.5	Conducted disturbances induced by surges	59
11.5.1	Requirements	59
11.5.2	Method of test and interpretation of the results	59
11.6	Conducted disturbances induced by radio-frequencies.....	59
11.6.1	Requirements	59
11.6.2	Method of test and interpretation of the results	59
11.7	50 Hz/60 Hz magnetic field	59
11.7.1	Requirements	59
11.7.2	Method of test and interpretation of the results	59
11.8	Voltage dips and short interruptions.....	59
11.8.1	Requirements	59
11.8.2	Method of test and interpretation of the results	60
12	Mechanical performance, requirements and tests	60
12.1	General.....	60
12.2	Drop test.....	60
12.2.1	Requirements	60
12.2.2	Method of test and interpretation of the results	60

12.3	Vibration test	61
12.3.1	Requirements	61
12.3.2	Method of test and interpretation of the results	61
12.4	Microphonics test.....	61
12.4.1	Requirements	61
12.4.2	Method of test and interpretation of the results	61
13	Software	62
13.1	General.....	62
13.2	Design and structure of the software	63
13.2.1	Requirements	63
13.2.2	Method of test.....	63
13.3	Identification of the software	63
13.3.1	Requirements	63
13.3.2	Method of test.....	63
13.4	Authenticity of the software and the presentation of results.....	64
13.4.1	Requirements	64
13.4.2	Method of test.....	64
13.5	Alarm and stop of system operation under abnormal operating conditions.....	64
13.5.1	Requirements	64
13.5.2	Method of test.....	64
13.6	Control of instrument parameters	65
13.6.1	Requirements	65
13.6.2	Method of test.....	65
13.7	Storage of measurement data	65
13.7.1	Requirements	65
13.7.2	Method of test.....	65
13.8	Transmission of data.....	66
13.8.1	Requirements	66
13.8.2	Method of test.....	66
13.9	Hardware interfaces and software interfaces.....	66
13.9.1	Requirements	66
13.9.2	Method of test.....	67
13.10	Documentation for the software test.....	67
13.10.1	Requirements	67
13.10.2	Method of test.....	67
14	Uncertainty	68
15	Documentation	68
15.1	Type test report	68
15.2	Certificate	68
16	Operation and maintenance manual	69
Annex A (normative)	Statistical fluctuations	70
Annex B (normative)	Coverage intervals	72
B.1	General.....	72
B.2	Coverage interval for the mean, $\bar{x}$	73
B.3	Coverage interval for a combined quantity	73
Annex C (informative)	Causal connection between readout signals, indicated value and measured value	75

Annex D (informative) Procedure to determine the variation of the relative response due to radiation energy and angle of radiation incidence	76
Annex E (informative) Computational method of test for mixed irradiations	78
Bibliography.....	80
Figure B.1 – Test for coverage interval	72
Figure C.1 – Data evaluation in dosimetry systems	75
Figure E.1 – Flow chart of a computer program to perform tests according to 8.2	79
Table 1 – Symbols and abbreviated terms	21
Table 2 – Reference conditions and standard test conditions	27
Table 3 – Radiation characteristics of $H_p(0,07)$ dosimeters for X, gamma and beta radiation	33
Table 4 – Radiation characteristics of $H_p(3)$ dosimeters for X, gamma and beta radiation	34
Table 5 – Radiation characteristics of $H_p(10)$ dosimeters for X and gamma radiation	35
Table 6 – Radiation characteristics of $H_p(10)$ dosimeters for neutron radiation	36
Table 7 – Values of c_1 and c_2 for w different dose values and n indications for each dose value	39
Table 8 – Electrical and environmental characteristics of dosimeters	55
Table 9 – Electromagnetic disturbance characteristics of dosimeters	57
Table 10 – Mechanical disturbances characteristics of dosimeters.....	60
Table A.1 – Number of instrument readings required to detect true differences (95 % level of confidence) between two sets of instrument readings on the same instrument.....	71
Table B.1 – Student's t -value for a double sided 95 % coverage interval.....	73
Table E.1 – Example of dosimeter response table and range limits.....	78

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RADIATION PROTECTION INSTRUMENTATION –
MEASUREMENT OF PERSONAL DOSE EQUIVALENTS FOR X,
GAMMA, NEUTRON AND BETA RADIATIONS –
ACTIVE PERSONAL DOSEMETERS**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 61526 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2010. This edition constitutes a technical revision.

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

- a) Modification of the title;
- b) Inclusion of the measurement quantity for the dose in the lens of the eye, $H_p(3)$;
- c) Inclusion of measurement quantity for dose in the skin and extremities, $H_p(0,07)$;

- d) Inclusion of dosimeters between active and passive: "hybrid dosimeters";
- e) Inclusion of software requirements;
- f) Harmonization of requirements for linearity to IEC 62387;
- g) Revised neutron energy response requirements.

The text of this International Standard is based on the following documents:

Draft	Report on voting
45B/1047/FDIS	45B/1049/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document 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

This document applies to active, (direct reading or hybrid) personal dosimeters and monitors used for measuring personal dose equivalents $H_p(10)$, $H_p(3)$, and $H_p(0,07)$, for X, gamma, neutron, and beta radiations.

For personal dose equivalent $H_p(10)$ and for X and gamma radiation, two minimum rated ranges for the photon energy are given. The first from 20 keV to 150 keV is for workplaces where low energy X-rays are used, e.g., in diagnostic medicine, the second from 80 keV to 1,25 MeV is for workplaces where high energy X-rays and/or gamma sources are used, e.g., in industry. For neutron radiation the minimum rated range of neutron energy is from 0,025 eV (thermal neutrons) to 10 MeV. The rated ranges can be extended to all energies covered by the respective standards for reference radiation fields.

For personal dose equivalent $H_p(3)$ and for X and gamma radiation, a minimum rated range for photon energy from 30 keV to 250 keV is given. For personal dose equivalent $H_p(0,07)$ a range of 30 keV to 1250 keV or, for workplaces where low energy X-rays are used, 20 keV to 150 keV, is given. For beta radiation for both quantities, the minimal rated range is from 0,24 MeV to 0,8 MeV (mean beta particle energy). The rated ranges can be extended to all energies covered by the respective standards for reference radiation fields.

In some applications, for example, at a nuclear reactor installation where 6 MeV photon radiation is present, measurement of personal dose equivalent (rate) $H_p(10)$ for photon energies up to 10 MeV should be required. In some other applications, measurement of $H_p(10)$ down to 10 keV should be required.

For personal dosimeters, requirements for measuring the dose quantities $H_p(10)$, $H_p(3)$, and $H_p(0,07)$, and for monitoring of the respective dose rate quantities are given. The measurement of these dose rate quantities is an option for personal dosimeters.

Establishments in some countries may be permitted to use this type of personal dosimeter as the dosimeter to provide the dose of record by an approved dosimetry service.

RADIATION PROTECTION INSTRUMENTATION – MEASUREMENT OF PERSONAL DOSE EQUIVALENTS FOR X, GAMMA, NEUTRON AND BETA RADIATIONS – ACTIVE PERSONAL DOSEMETERS

1 Scope

This document applies to personal dosimeters with the following characteristics:

- a) They are worn on the trunk, close to the eye, or on the extremities.
- b) They measure the personal dose equivalents $H_p(10)$, $H_p(3)$, and $H_p(0,07)$, from external X and gamma, neutron (not for $H_p(3)$), and beta radiations, and may measure the respective personal dose equivalent rates for the same radiations (for alarming purposes).
- c) They have a digital indication. This indication may or may not be attached.
- d) They have alarm functions for the personal dose equivalents or personal dose equivalent rates except for hybrid dosimeters. For hybrid dosimeters an alarm function for the personal dose equivalents shall be implemented in the associated readout system.

NOTE 1 When reference is made in this document to "dose", this is meant to indicate personal dose equivalent, unless otherwise stated.

NOTE 2 When reference is made in this document to "dosimeter", this is meant to include all personal dosimeters, unless otherwise stated.

NOTE 3 This document does not cover neutron dosimeters for the $H_p(3)$ measurements up to now.

This document specifies requirements for the dosimeter and, if supplied, for its associated readout system.

Usually, a dosimeter is not able to measure all quantities given above. Thus, the dosimeter is only tested with regard to those quantities and types of radiation it is intended to be used for. Other types of radiation are considered as influence quantities which also may have requirements.

This document specifies, for the dosimeters described above, general characteristics, general test procedures, radiation characteristics as well as electrical, mechanical, safety and environmental characteristics. The only requirements specified for associated readout systems are those which affect its accuracy of readout of the personal dose equivalent and alarm settings, and those which concern the influence of the reader on the dosimeter.

This document does not cover special requirements for accident or emergency dosimetry, although the dosimeters may be used for this purpose.

This document does not apply to dosimeters used for measurement of pulsed radiation, such as radiation emanating from many medical diagnostic X-ray facilities, linear accelerators or similar equipment.

NOTE 4 Requirements and testing procedure for dosimeters used in pulsed field of ionizing radiation can be found in IEC TS 63050 or IEC TS 62743.

This document does not apply for dosimeters to measure ambient or directional dose equivalent.

NOTE 5 Requirements for ambient or directional dose equivalent meters can be found e.g. in: IEC 60846-1; IEC 62387, IEC 61017 or IEC 60532.

2 Normative references

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

IEC 60050-395:2014, *International Electrotechnical Vocabulary (IEV) – Part 395: Nuclear instrumentation – Physical phenomena, basic concepts, instruments, systems, equipment and detectors*

IEC 60050-395:2014/AMD1:2016

IEC 60050-395:2014/AMD2:2020

IEC 60068-2-31:2008, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60086-1:2021, *Primary batteries – Part 1: General*

IEC 60086-2:2021, *Primary batteries – Part 2: Physical and electrical specifications*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60904-3, *Photovoltaic devices – Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data*

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

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

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

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

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

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

IEC 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*

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

IEC 61187:1993, *Electrical and electronic measuring equipment – Documentation*

IEC 62387:2020, *Radiation protection instrumentation – Dosimetry systems with integrating passive detectors for individual, workplace and environmental monitoring of photon and beta radiation*

IEC TR 62461:2015, *Radiation protection instrumentation – Determination of uncertainty in measurement*

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

ISO/IEC Guide 98-3:2008/Suppl.1:2008, *Propagation of distributions using a Monte Carlo method and Corr.1* (2009)

ISO 4037-1:2019, *Radiological protection – X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods*

ISO 4037-2:2019, *Radiological protection – X and gamma reference radiation for calibrating dosimeters 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 4037-3:2019, *Radiological protection – X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosimeters and the measurement of their response as a function of energy and angle of incidence*

ISO 4037-4:2019, *Radiological protection – X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy – Part 4: Calibration of area and personal dosimeters in low energy X reference radiation fields*

ISO 6980-1:2023, *Nuclear energy – Reference beta-particle radiation – Part 1: Methods of production*

ISO 6980-2:2023, *Nuclear energy – Reference beta-particle radiation – Part 2: Calibration fundamentals related to basic quantities characterizing the radiation field*

ISO 6980-3:2023, *Nuclear energy – Reference beta-particle radiation – Part 3: Calibration of area and personal dosimeters and the determination of their response as a function of beta radiation energy and angle of incidence*

ISO 8529-1:2021, *Reference neutron radiations – Part 1: Characteristics and methods of production*

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

ISO 8529-3:2023, *Neutron reference radiation fields – Part 3: Calibration of area and personal dosimeters and determination of their response as a function of neutron energy and angle of incidence*

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 21909-1:2021, *Passive neutron dosimetry systems – Part 1: Performance and test requirements for personal dosimetry*

ISO 80000-10:2019, *Quantities and units – Part 10: Atomic and nuclear physics*

ICRU Report 51:1993, *Quantities and units in radiation protection dosimetry*

ANSI N42.17A, *American National Standard For Performance Specifications For Health Physics Instrumentation – Portable Instrumentation For Use In Normal Environmental Conditions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-395, IEC 60529 and ICRU Report 51, as well as the following apply.

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

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

3.1

acceptance test

contractual test to prove to the customer that the device meets certain conditions of its specification

[SOURCE: IEC 60050-151:2001, 151-16-23]

3.2

active personal dosimeter

dosemeter measuring personal dose equivalent using electronic components (e.g. either a direct reading dosimeter or a hybrid personal dosimeter including the associated readout system)

3.3

calibration

quantitative determination of the reference calibration coefficient, N_0 , and the correction for non-constant response, r_n , under a controlled set of standard test conditions for which all the m relative response values, r_q , are unity and all the l deviations, D_p , are zero

Note 1 to entry: Methods of calibration are given in ISO 4037 for photons, ISO 6980 for beta and ISO 8529 for neutron radiations. Determinations concerning the build-up and phantom as given in these standards should be taken into account during the calibration of the dosimeter, for the use of phantoms see 7.5.

3.4 calibration coefficient

N

quotient of the conventional quantity value of a quantity, H_r , and the indicated value, G_r , at the point of test for a specified reference radiation under specified reference conditions. It is expressed as

$$N = \frac{H_r}{G_r}$$

Note 1 to entry: The calibration coefficient N is dimensionless when the instrument indicates the quantity to be measured, then N is equal to the calibration factor. A dosimeter indicating the conventional quantity value correctly has the calibration coefficient of one.

[SOURCE: ISO 29661:2012, 3.1.5, modified: replaced notes by new one.]

3.5 coefficient of variation

ratio of the standard deviation s to the arithmetic mean $\bar{x}$ of a set of n measurements x_i given by the following formula:

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

3.6 combined standard measurement uncertainty combined standard uncertainty

u_c

standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the input quantities in a measurement model

Note 1 to entry: In case of correlations of input quantities in a measurement model, covariances must also be taken into account when calculating the combined standard measurement uncertainty; see also ISO/IEC Guide 98-3:2008, 2.3.4.

[SOURCE: ISO/IEC Guide 98-3:2008, 2.31]

3.7 conventional quantity value conventional value of a quantity conventional value

quantity value attributed by agreement to a quantity for a given purpose

Note 1 to entry: The term "conventional true quantity value" is sometimes used for this concept, but its use is discouraged.

Note 2 to entry: Sometimes a conventional quantity value is an estimate of a true quantity value.

Note 3 to entry: A conventional quantity value is generally accepted as being associated with a suitably small measurement uncertainty, which might be zero.

[SOURCE: ISO/IEC Guide 99:2007, 2.12, modified: skipped examples.]

3.8 correction for non-constant response

r_n

quotient of the response, R , under specified conditions where only the quantity to be measured is varied, and the reference response, R_0 . It is expressed as:

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

Note 1 to entry: For an instrument with constant response, r_n is equal to one.

3.9 detector assembly

assembly of a radiation detector and the associated components needed for converting signal from the accumulated dose or prevailing dose rate integrated over time to dose measurand

Note 1 to entry: The detector assembly contains both mechanical parts, e.g. energy filtering and electrical parts e.g. which convert the active detector signal to detectable pulse indication (of active detector) or passive detector signal to monotonically changing voltage or current signal.

EXAMPLE A personal dosimeter is to be calibrated using a phantom. The combination of personal dosimeter and phantom and possibly further reading instruments and cables comprise one detector assembly.

3.10 deviation

D

difference between the indicated values for the same value of the measurand of a dose(rate) meter, when an influence quantity assumes, successively, two different values

$$D = G - G_r$$

where G is the indicated value under the effect of an influence quantity, and G_r is the indicated value under reference conditions.

[SOURCE: IEC 60050-311:2001, 311-07-03, modified: The original term reads "variation (due to an influence quantity)". In order not to confuse variation (of the indicated value) and variation of the response, in this document, the term is called "deviation".]

3.11 direct reading personal dosimeter

personal dosimeter having a direct, e.g. digital, indication of the dose received

3.12 effective range of measurement

range of values of the quantity to be measured over which the performance of a dosimeter meets the requirements of this document

3.13 expanded measurement uncertainty 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 level of confidence of 95 % is recommended for the use of this document.

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.5, modified: Added "expanded measurement uncertainty", skipped notes, added new notes.]

3.14 hybrid dosimeter

dosimeter without real time direct dose indication, i.e. no dose display, with either active detector, i.e. semiconductor based, non-integrating, and associated electronics or passive, i.e. integrating, detector and circuitry of electronic components performing the dose signal to digital value conversion, and associated readout system for dose calculation and indication and other operational functions

3.15 indicated value

G

value given by the indication of the dosimeter, e.g. by its display or associated read-out system (hybrid dosimeters)

3.16 influence quantity

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

Note 1 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 document, this is the case for the influence quantities "radiation energy and angle of radiation incidence".

[ISO/IEC Guide 98-3:2008, B.2.10, modified: skipped examples.]

3.17 influence quantity of type F

influence quantity whose effect on the indicated value is a change in response

Note 1 to entry: Examples are radiation energy and angle of radiation incidence (see 9.4 to 9.6) and dose rate when measuring the dose.

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

3.18 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: Examples are electromagnetic disturbance (see Clause 11) and microphonics (see 12.4).

Note 2 to entry: "S" stands for sum: The indication is the sum of the indication due to radiation and due to the influence quantity, e.g., electromagnetic disturbance.

3.19**lower limit of effective range of measurement** H_0

lowest dose value included in the effective range of measurement

3.20**maximum possible measuring time** $t_{\max}$

longest measuring time within which all requirements of this document are fulfilled

Note 1 to entry: The time can be given by the battery life or by other requirements, see note to 9.3.6.

Note 2 to entry: The time may strongly depend on the desired usage of the dosimeter e.g. reading every day or like a passive dosimeter reading at the end of a month.

3.21**measured value** M value that can be obtained from the indicated value G by applying the model function for the measurement**3.22****minimum rated range**

smallest range being specified of an influence quantity or instrument parameter over which the dosimeter will operate within the respective variation of the relative response in order to comply with this document

3.23**model function**function for calculation of the measurement results from the indicated value G and known corrections

Note 1 to entry: The model function is necessary to evaluate the uncertainty according to ISO/IEC Guide 98-3:2008, 3.1.6, 3.4.1 and 4.1.

Note 2 to entry: An example of a model function is given here. It combines the indicated value G with the reference calibration coefficient N_0 , the correction for non-constant response 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:

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

Note 3 to entry: The calculations according to such model function are usually not performed, only in the case that specific influence quantities are well known and an appropriate correction is applied.

3.24**non-constant response**

variation of the value of the (relative) response with the magnitude of the quantity to be measured

3.25**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: Typical depths are 0,07 mm, 3 mm and 10 mm.

[SOURCE: ICRU Report 51:1993]

3.26

personal dosimeter

personal dose equivalent meter

dosimeter worn by a person to determine the personal dose equivalent received

[SOURCE: IEC 60050-395:2014, 395-05-08, modified, skipped notes and dosimeter.]

3.27

personal dose equivalent rate

$\dot{H}_p(d)$

differential quotient of $H_p(d)$, with respect to time:

$$\dot{H}_p(d) = \frac{dH_p(d)}{dt}$$

Note 1 to entry: Units of personal dose equivalent rate are a quotient of the sievert or its decimal multiples or submultiples by a suitable unit of time (for example, mSv h⁻¹).

3.28

point of test

point at which the conventional quantity value is determined and at which the reference point of the detector assembly is placed for calibration and test purposes

[SOURCE: ISO 29661:2012, modified, replaced “known” by “determined and at which the reference point of the detector assembly is placed for calibration and test purposes”.]

3.29

qualification tests

tests which are performed in order to verify that the requirements of a specification are fulfilled. Qualification tests are subdivided into type tests and routine tests

3.30

rated range

range of a quantity to be measured, observed, supplied, or set assigned to the instrument

3.31

rated range of use

range of values of an influence quantity giving the limits of operation within the stated limits of the relative response or the deviation

3.32

reference calibration coefficient

calibration coefficient, N_0 , for a reference value, $H_{r,0}$, of the quantity to be measured. With $G_{r,0}$ being the respective indicated value, it is expressed as:

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

Note 1 to entry: For the value of $H_{r,0}$ see Table 2.

Note 2 to entry: $N_0 = \frac{1}{R_0}$.

3.33**reference operating condition**
reference condition

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

3.34**reference orientation**

orientation of the detector assembly with respect to the direction of the incident radiation stated by the manufacturer

3.35**reference point (of a detector assembly)**

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

Note 1 to entry: The point from which the distance to the source is measured.

Note 2 to entry: The reference point should not be the phantom front surface to not induce a bias at small source to dosimeter distances used e.g. for beta irradiations.

Note 3 to entry: The quantities are defined in the person.

3.36**reference response** R_0

response of the assembly under reference conditions:

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

where $H_{r,0}$ is a reference (conventional) quantity value of the quantity to be measured for a specified reference radiation under specified reference conditions and $G_{r,0}$ is the respective indicated value.

Note 1 to entry: $R_0 = \frac{1}{N_0}$.

3.37**relative expanded uncertainty** U_{rel}

expanded uncertainty divided by the result of the measurement

3.38**relative response** r

ratio of the response, R , and the reference response, R_0 , at the point of test under specified conditions:

$$r = \left(\frac{R}{R_0} \right) \times 100\%$$

**3.39
response (of a radiation measuring assembly)** **R**

ratio, under specified conditions, given by the relation:

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

where

G is the value of the quantity measured by the equipment or assembly under test, and

H is the conventional quantity value of this quantity

Note 1 to entry: For an instrument with non-constant response, the value of the response varies when the conventional quantity value is changed.

[SOURCE: IEC 60050-395:2014, 395-03-72, modified, replaced ν and ν_c by G and H , deleted notes.]

**3.40
routine test**

conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-151:2001, 151-16-17]

**3.41
standard test conditions**

value, values, or range of values of an influence quantity or instrument parameter, which are permitted when carrying out calibrations or tests on another influence quantity or instrument parameter (see column 3 of Table 2)

**3.42
standard measurement uncertainty
standard uncertainty of measurement
standard uncertainty** **u_i**

measurement uncertainty expressed as a standard deviation

[ISO/IEC Guide 98-3:2008, 2.3.1]

**3.43
supplementary tests**

tests intended to provide supplementary information on certain characteristics of the dosimeters

**3.44
type test**

conformity test made on two or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16 modified: two or more instead of one or more.]

3.45**measurement uncertainty
uncertainty of measurement
uncertainty**

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to a measurand [VIM 3.9]

Note 1 to entry: VIM 3.9 is 2nd version of VIM, in 3rd Version it is 2.26.

[SOURCE: IEC 60050-311:2001, 311-01-02 modified: skipped notes.]

4 Units and symbols**4.1 Units**

In the present document, the units of the International System (SI) are used. The definition of radiation quantities and dosimetric terms is given in IEC 60050-395, ISO 80000-10:2019 and ICRU Report 51. In addition, the following units are accepted:

- For energy: electron-volt (symbol eV). $1 \text{ eV} = 1,602 \cdot 10^{-19} \text{ J}$.
- For time: year, day (symbol d), hour (symbol h), minute (symbol min).

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

The SI unit of dose equivalent is the sievert (symbol Sv). $1 \text{ Sv} = 1 \text{ J kg}^{-1}$.

4.2 Symbols

Table 1 gives a list of the symbols and abbreviated terms used.

Table 1 – Symbols and abbreviated terms

Symbol	Meaning	Unit
α	Angle of radiation incidence	deg
α_{max}	Maximum value of α within rated range of use	deg
C_K	conventional quantity value for radiation quality K	Sv
C_{K+L}	conventional quantity value for combined irradiation with radiation quality K and L	Sv
C_L	conventional quantity value for radiation quality L	Sv
$D_p, (\dot{D}_p)$	Deviation due to influence quantity no. p of type S	Sv (Sv h ⁻¹)
$\bar{E}$	Fluence weighted mean radiation energy	eV
$f(S_g)$	Function for evaluation of the indicated value from the detector signals S_g	—
$G, (\dot{G})$	Indicated dose(rate) value	Sv (Sv h ⁻¹)
G_a	Indicated dose value at which the alarm occurs	Sv
$\hat{G}_{\text{high}}$	Stabilized dose rate reading after an increase in dose rate	Sv h ⁻¹
G_K	Indicated dose value due to a single irradiation with the conventional quantity value C_K	Sv
G_{K+L}	Indicated dose value due to a (simultaneously) combined irradiation with the conventional quantity value $C_K + C_L$	Sv
G_L	Indicated dose value due to a single irradiation with the conventional quantity value C_L	Sv

Symbol	Meaning	Unit
$G_{\text{low},1}$	Indication of the dosimeter under the same conditions as given for G_{nom} , but when the battery voltage is low, for example, the dosimeter indicates "Low battery" for the first time.	Sv
Δg_{mix}	Relative change in indication caused by subsequent and mixed (simultaneously) exposure, see Clause 8	—
G_{nom}	Indication of the dosimeter under given conditions when the battery voltage has its nominal value.	Sv
G_{nat}	Accumulated dose in the environment	Sv
$G_r, \dot{G}_r$	Indicated dose(rate) value under specified reference conditions	Sv (Sv h ⁻¹)
$G_{r,0}, \dot{G}_{r,0}$	Value of the indicated dose(rate) due to exposure to reference dose $H_{r,0}$	Sv (Sv h ⁻¹)
$H, (\dot{H})$	Conventional quantity value of the dose (rate)	Sv (Sv h ⁻¹)
$H_0, \dot{H}_0$	Lower dose(rate) limit of the effective range of measurement	Sv (Sv h ⁻¹)
H_a	Dose value to which the alarm is set	Sv
$H_{a,c}$	Conventional quantity value of the dose at which the alarm occurs	Sv
$\dot{H}_a$	Dose rate value to which the alarm is set	Sv h ⁻¹
$H_p(0,07)$	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
$\dot{H}_p(0,07)$	Personal dose equivalent rate at a depth 0,07 mm	Sv h ⁻¹
$\dot{H}_p(3)$	Personal dose equivalent rate at a depth 3 mm	Sv h ⁻¹
$\dot{H}_p(10)$	Personal dose equivalent rate at a depth 10 mm	Sv h ⁻¹
$H_p(d)$	Dose equivalent in soft tissue at a specified point in the human body at a depth d	Sv
$H_r, (\dot{H}_r)$	Conventional quantity value of the dose(rate) under specified reference conditions	Sv (Sv h ⁻¹)
$H_{r,0}, (\dot{H}_{r,0})$	Reference dose(rate) value of the quantity to be measured	Sv (Sv h ⁻¹)
H_{nat}	Personal dose equivalent due to natural environmental radiation	Sv
$\dot{H}_{\text{nat}}$	Personal dose equivalent rate due to natural environmental radiation	Sv h ⁻¹
$I_{\text{low},1}$	Supply current of the dosimeter when the indication is $G_{\text{low},1}$	A
$I_{\text{low},2}$	Supply current of the dosimeter when the alarm sounds and the visual alarm is displayed after the alarm is set on its lowest range	A
K	Symbol of radiation condition K, for example, 3 mSv and N-80	—
k	Coverage factor (see ISO/IEC Guide 98-3)	—
L	Symbol of radiation condition L, for example, 4 mSv and S-Co	—
l	Number of influence quantities of type S	—
$M, (\dot{M})$	Measured dose(rate) value	Sv (Sv h ⁻¹)
m	Number of influence quantities of type F	—
N	Calibration coefficient	—
n	Number of indicated values for one dose value used for the test of constancy of dose response and coefficient of variation	—
N_0	Reference calibration coefficient	—
Q_{nom}	Nominal capacity of the batteries	A h
R	Response	—
r	Relative response	—

Symbol	Meaning	Unit
R_0	Reference response	—
r_n	Correction for non-constant response	—
r_q	Relative response due to influence quantity no. q of type F	—
S_g	Signal of dosimeter's element g	—
S_K	Symbol of radiation quality of condition K, for example, N-80	—
S_L	Symbol of radiation quality of condition L, for example, S-Co	—
t_{env}	Measuring time in the environment	h
t_{max}	Maximum possible measuring time (3.20)	h
U	Expanded uncertainty	As quantity
u_c	Combined standard uncertainty	As quantity
u_i	Standard uncertainty due to component i	As quantity
$U_{low,1}$	Battery voltage under conditions prevailing for the determination of $G_{low,1}$	V
$U_{low,2}$	Battery voltage under the same conditions as given for G_{nom} , but when the battery voltage is lowered until the indication of the dosimeter is 0,9 G_{nom}	V
U_{nom}	Nominal value of the battery voltage	V
U_{rel}	Relative expanded uncertainty	—
v	Coefficient of variation	—
v_{max}	Maximum permitted coefficient of variation at the dose rate to which the alarm is set	—
w	Number of dose values used for the test of constancy of the dose response and coefficient of variation	—

5 Mechanical characteristics

5.1 Case

The case should be at least protection class IP 54 (see 10.6). Means shall be provided for fixing the dosimeter to clothing, for example, a strong clip, ring or a lanyard. The design of the dosimeter should assist it being worn in a position that ensures the necessary orientation of the detector and of existing alarm indicators.

Should the dosimeter be used for extremity monitoring, then the extremity detector should be identified with the proper wearing orientation. The electronics case may be removed from the measurement position. A means of securely fixing the remote electronics to the user's clothing should be provided such that any alarms are easily identified, as well as a recommended method of attaching the extremity detector.

NOTE IEC 62706 suggests to use IP 54.

5.2 Switches

If external switches are provided, these shall be adequately protected from accidental or unauthorized operation. Operation of such switches shall not interfere with the integrating function of the dosimeter. Switches shall be operable beneath a plastic bag and with gloved hands.

6 General characteristics

6.1 Storage of dose information

The personal dosimeter shall retain the stored dose information under all normal circumstances.

6.2 Indication

Any dose indication for personal dosimeters shall be digital and shall be shown in units of dose equivalent, namely sieverts and its submultiples, for example, microsieverts (μSv). The indication shall clearly indicate the unit of the quantity being measured. If a display exists, it shall be clearly visible and be easy to read by the wearer.

NOTE 1 For hybrid dosimeters no display on the device might exist. The dose indication might be available by an external display or readout system.

NOTE 2 To avoid significant underestimates of cumulative dose when multiple short exposures are added together, it is recommended that doses of less than H_0 are indicated by the dosimeter, even though with large statistical inaccuracy, rather than showing as zero. This means that cumulative doses from several low-dose exposures can be reliably estimated by adding indicated doses from multiple exposures when wearing different dosimeters for each activity.

6.3 Dosimeter markings

The reference point for calibration and test purposes shall be indicated on the outside of the dosimeter or should be clearly given in the instruction manual. If there is no mark or marks on the outside of the dosimeter, the geometric centre of the dosimeter should be taken as the reference point. There may be different marks for different measurement quantities.

The reference orientation with respect to the wearer shall also be marked on the dosimeter or clearly given in the instruction manual.

6.4 Retention of radioactive contamination

The dosimeter shall be designed to minimize the retention of contamination and to ease its removal. A dosimeter may be provided with an additional protective cover; if fitted, the dosimeter shall still conform to the requirements of this document.

6.5 Ranges for dose and dose rate

The dose and dose rates to be measured are stated in lines 1 of Table 3 to Table 6.

Where more than one detector is used for measurements over the complete range, the results shall be derived and displayed automatically. Where the dosimeter has range change facilities, these shall be automatic.

6.6 Rated range of an influence quantity

The rated range of any influence quantity has to be stated by the manufacturer in the documentation, it shall cover at least the minimum rated range given in the third column of Table 3 to Table 6 and Table 8 to Table 10. All requirements of this document shall be fulfilled within the whole rated range.

Personal dosimeters are designed for specific applications so the manufacturers should specify the types of radiation, the measuring range, the energy ranges and the ranges of all other influence quantities in which their dosimeters are designed for (see 15.2).

6.7 Effect of radiation not intended to be measured and use of more than one dosimeter

If dosimeters are intended to be used in radiation fields for which they are not specified, for example, a neutron and a photon dosimeter together in a mixed neutron/photon field, the effect of radiation not intended to be measured shall be considered as an influence quantity. For the mentioned example, it follows that photon radiation is an influence quantity for the dosimeter only designed and specified for neutrons and vice versa. For each dosimeter designed for the measurement of a specific radiation, the manufacturer shall specify the deviation of this dosimeter if exposed to other radiation types (this should be checked during testing at least under 0° incident angle). From this information, in the case of use of more than one dosimeter, the user can estimate the total dose value and the associated uncertainties.

NOTE 1 Requirements for effect of beta radiation are given in 9.6.3 and 9.6.4.

NOTE 2 The effect of the radiation not intended to be measured may be dose rate dependent, e.g. photons may have an effect only at higher dose rates on the indication of a neutron dosimeter.

6.8 Intrinsic and environmental background of the instrument

For personal dosimeters for dose from X and gamma radiations, the indication due to instrument artefacts shall be given by the manufacturer for an integrating period equivalent to the maximum possible measuring time $t_{\max}$, for test see 9.3.5.

For dosimeters for beta and neutron radiation, the indication due to instrument artefacts should be given by the manufacturer for an integrating period equivalent to the maximum possible measuring time $t_{\max}$. A test can be done according to 9.3.5b).

Each different detector of the dosimeter needs to be tested.

This value is required if measured values of dose equivalents accumulated during several days, e.g. for one month, and measured using different dosimeters are compared.

6.9 Dose or dose rate alarms

6.9.1 General

Direct reading dosimeters shall provide and hybrid dosimeters may provide at least one alarm such that the user has no need to look at the display (e.g., optical, vibrational or audible alarm).

For personal dosimeters, it shall not be possible to set alarm levels or deactivate the alarm completely by external switches on the dosimeter. The alarm levels and deactivation shall be set by the readout system (that is provided by the manufacturer) or by an electronic or mechanical system with restricted access (e.g., password protection). It shall be possible to inhibit unauthorized change of alarm levels or deactivation.

6.9.2 Dose alarms

If the alarm cannot be freely set to any value in the effective range of measurement, setting it to at least one value in each order of magnitude over the complete effective range of measurement of the dosimeter (for example, 30 μSv , 0,3 mSv, 3 mSv and 30 mSv) shall be possible.

6.9.3 Dose rate alarms

If the alarm cannot be freely set to any value in the effective range of measurement, setting it to at least one value in each order of magnitude over the complete effective range of measurement of the dosimeter (for example, 30 $\mu\text{Sv h}^{-1}$, 0,3 mSv h^{-1} , 3 mSv h^{-1} and 30 mSv h^{-1}) shall be possible.

6.9.4 Alarm output

a) Location

The audible and/or visual alarm shall be located so that when the dosimeter is worn on the body, the audible alarm can be heard and the visual alarm seen by the wearer.

b) Audible alarm

The frequency should be within the 1 kHz to 5 kHz range. Where an intermittent alarm is provided, the signal interval shall not exceed 2 s. The A-weighted sound level (impulse level for intermittent alarm) should exceed 80 dBA and not exceed 100 dBA at 30 cm from the alarm source for a whole body dosimeter.

NOTE A visual or vibration signal or earphones capability may be useful for high noise environments or someone who is hard of hearing.

6.10 Indication of malfunction

Indication shall be given of operation conditions in which the accumulation of dose equivalent is not accurate (within the specifications of this document), for example originating from: low battery supply, detector failure, electronic failure, unintended change of dosimeter software, or when used in high dose rate fields.

NOTE This requirement is also applicable to hybrid dosimeter. An option might be indication by LED or during the read out process.

6.11 Assignment of the dose value to the dosimeter

Every indicated and recorded value shall be unambiguously assigned to the dosimeter from which it originated. This shall be ensured for hybrid dosimeters and detached sensors that do not have an integral display but are only read with a separate reader.

NOTE One possible solution is to display the reading along with the serial number for detached sensors or dosimeters with no direct indication and readout by a reader.

6.12 Algorithm to evaluate the indicated value

For the type test according to this document, the manufacturer shall deliver the evaluation algorithm of the indicated value starting from the signal(s) of the detector(s). The documentation shall be in a form that allows a complete understanding of the calculations and/or the decision tree. It is not required for dosimeters using linear algorithms.

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 For details of signal, evaluated value and evaluation algorithm refer to Annex C.

This algorithm may be proprietary and confidential and only be used by the testing laboratory for the purpose of type testing.

7 General test procedures

7.1 Nature of tests

Unless otherwise specified in the individual clauses, all the tests enumerated in this document are to be considered as type tests. Certain tests may be considered as acceptance tests by agreement between the purchaser and the manufacturer or supplier.

7.2 Reference conditions and standard test conditions

Reference conditions are given in the second column of Table 2. Except where otherwise specified, the tests in this document shall be carried out under standard test conditions given in the third column of Table 2. For those tests carried out under standard test conditions, the values of temperature, pressure, and relative humidity at the time of test shall be stated and the appropriate corrections made to give the response under reference conditions. The values of any corrections shall be stated.

For those tests intended to determine the effects of variations in the influence quantities given in Table 2, all other influence quantities shall be maintained within the limits for standard test conditions given in Table 2, unless otherwise specified in the test procedure concerned.

Table 2 – Reference conditions and standard test conditions

Influence quantity	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Photon radiation energy for: $H_p(10)$, $H_p(3)$, $H_p(0,07)$	S-Cs (ISO 4037-3)	S-Cs (ISO 4037-3)
Beta radiation energy, $H_p(0,07)$	$^{90}\text{Sr}/^{90}\text{Y}$ (ISO 6980)	$^{90}\text{Sr}/^{90}\text{Y}$ (ISO 6980)
Neutron radiation energy, $H_p(10)$	^{241}Am -Be or ^{252}Cf ^{a)}	^{241}Am -Be or ^{252}Cf ^{a)}
Angle of incidence of radiation	Reference direction given by the manufacturer	Direction given $\pm 2^\circ$
Dose for: $H_p(10)$, $H_p(3)$ $H_p(0,07)$	$H_{r,0}$: 0,3 mSv 3 mSv	0,1 mSv to 10 mSv ^{b)} 0,5 mSv to 50 mSv ^{b)}
Dose rate for: $\dot{H}_p(10)$, $\dot{H}_p(3)$ $\dot{H}_p(0,07)$	0,3 mSv h ⁻¹ 3 mSv h ⁻¹	0,1 mSv h ⁻¹ to 10 mSv h ⁻¹ ^{b)} 0,5 mSv h ⁻¹ to 50 mSv h ⁻¹ ^{b)}
Stabilization time	15 min	≥ 15 min
Ambient temperature	20 °C	18 °C to 22 °C ^{c)}
Relative humidity	65 %	50 % to 75 % ^{c)}
Atmospheric pressure	101,3 kPa	86,0 kPa to 106,6 kPa ^{c)}
Battery voltage	Nominal voltage	Battery used up to half of its useful life
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
Orientation of dosimeter (geotropism)	To be stated by the manufacturer	Stated orientation $\pm 5^\circ$
Dosimeter controls	Set up for normal operation	Set up for normal operation
Natural radiation background	Ambient dose rate of 0,1 $\mu\text{Sv h}^{-1}$	Less than ambient dose rate of 0,25 $\mu\text{Sv h}^{-1}$
Contamination by radioactive elements	Negligible	Negligible
^{a)} Other sources may be used if necessary. ^{b)} The actual value of the dose (rate) at the time of test shall be stated. ^{c)} The actual values of these quantities at the time of test shall be stated. These values are applicable for temperate climates. In hotter or colder climates, the actual values of the quantities at the time of test shall be stated. Similarly, a lower limit of pressure of 70 kPa may be permitted at high altitudes.		

7.3 Tests for influence quantities of type F

These tests may be performed at any value of the quantity to be measured above $10 H_0$. From the result of each test, the respective variation of the relative response r can be determined.

It is accepted that some small part of the effects of the influence quantities classified as Type F could be regarded as the effects produced by Type S influence quantities. If these effects are small they shall be ignored in relation to the use of this document. If during testing larger effects of Type S are observed, then the respective test shall be performed at a dose value of $10 H_0$ and these findings shall be reported in the type test report.

7.4 Tests for influence quantities of type S

These tests shall be performed at a conventional quantity value of the dose H of not more than 10 times the lower limit H_0 of the effective range of measurement, e.g. at $7 \times H_0$. The result of each test is a deviation D_p .

It is accepted that some small part of the effects of the influence quantities classified as Type S could be regarded as the effects produced by Type F influence quantities. If these effects are small they should be ignored in relation to the use of this document. If during testing larger effects of Type F or significant negative effects are observed, then the respective test shall be performed at a dose value of $10 H_0$ and these findings shall be reported in the type test report.

Due to the generally lower indicated value when compared to tests according to 7.3, the necessary number of measurements may be increased.

7.5 Phantom for testing

For all tests involving the use of a phantom, the phantoms given in ISO 4037-3 shall be used, i.e. slab, pillar, cylinder and rod phantom. For beta radiation the ISO water slab and cylinder phantom can be replaced by a polymethylmethacrylate (PMMA) slab, 200 mm × 200 mm × 20 mm (see ISO 6980-3:2023, 7.3.1).

For $H_p(0,07)$ the rod phantom shall be used for extremity dosimeters and the slab phantom for whole body dosimeters.

For $H_p(3)$ the cylinder phantom shall be used.

The required irradiation geometry is specified in the appropriate ISO reference standard (ISO 4037-3, ISO 6980-3 or ISO 8529-3).

7.6 Position of detector assembly for the purpose of testing

For all tests involving the use of radiation, the reference point of the detector assembly shall be placed at the point of test and it shall be oriented with respect to the direction of the radiation field as given by the reference orientation, except for tests with variations of the angle of radiation incidence.

7.7 Position of dosimeter during use

If the dosimeter design permits the user to wear the dosimeter in two orientations, one with the reference orientation pointing to the body of the user and one pointing away from the body – for example, a credit card size dosimeter – then the dosimeter shall fulfil the requirements of this document for both orientations or it shall clearly be stated at least in the manual that wearing in the wrong orientation can cause erroneous results and the correct orientation has to be clearly marked on the dosimeter, e.g. by "bodyside".

7.8 Minimum rated range of influence quantity

The minimum rated range of any specified influence quantity is given in the third column of Table 3 to Table 6 and Table 8 to Table 10.

7.9 Low dose rates

For the measurement of low dose rates of photon and beta radiation, it is necessary to take into account the contribution of natural background radiation to the dose rate at the point of test. The indication due to natural background radiation shall be subtracted from the indicated value during irradiation.

7.10 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuations of the indication arising from the random nature of radiation alone, is a significant fraction of the variation of the indication permitted in the test, then sufficient readings shall be taken to ensure that the mean value of such readings may be estimated with sufficient accuracy to determine whether the requirements for the characteristic under test are met.

NOTE 1 Increasing the number of readings makes the estimation of the mean more accurate as it reduces the standard uncertainty.

The interval between such readings shall be sufficient to ensure that the readings are statistically independent.

NOTE 2 This time interval may be dose rate dependent.

The number of readings required to settle the true difference between two sets of fluctuating dosimeter readings on the same instruments under unchanged conditions is given in Table A.1.

NOTE 3 For details on statistical fluctuation, refer to Annex A.

7.11 Production of reference radiation

Unless otherwise specified in the individual methods of test, all tests involving the use of X, gamma, neutron, or beta radiations shall be carried out with the relevant specified type of radiation (see Table 2). The nature, construction and conditions of use of the radiation sources shall be in accordance with the following recommendations:

- a) ISO 4037-1/ISO 4037-2/ISO 4037-3/ISO 4037-4;
- b) ISO 6980-1/ISO 6980-2/ISO 6980-3;
- c) ISO 8529-1/ISO 8529-2/ISO 8529-3 and ISO 12789.

8 Additivity of indicated value

8.1 Requirements

The following requirement is fulfilled for dosimetry systems using only linear combinations or linear optimizations to obtain the signal and finally the indicated value, and no tests are required (the algorithm is an additive one).

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

- a) a difference in the dose values, and / or
- b) a difference in the value of one specific influence quantity (for example different energy and angle of radiation incidence), or
- c) a different type of radiation if the dosimetry is tested with respect to more than one type of radiation.

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

NOTE 1 This requirement ensures that the results of the test according to this document are also valid if the dosimeter 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.

EXAMPLE: A dosimetry system with a non-linear evaluation algorithm can have the following characteristic: Assuming two dosimeters (A and B) are irradiated with the same dose equivalent of 20 mSv ^{137}Cs , 0°. Afterwards, dosimeter B is irradiated additionally with 2 mSv, N-40, 0°. The indicated value of dosimeter A might be 22 mSv ($R = 22 \text{ mSv} / 20 \text{ mSv} = 1,1$) and the indication of dosimeter B might be 21 mSv ($R = 21 \text{ mSv} / 22 \text{ mSv} = 0,95$). For both dosimeters, the relative response (assuming $R_0 = 1$) is within the required range from 0,71 up to 1,67 (i.e. the requirement of 9.4.3.1 is fulfilled), but the indicated value is not additive.

8.2 Method of test

8.2.1 General

This test has to be performed via calculations using the signals of the dosimeter 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 dosimeters' elements.

8.2.2 Preparation of the test

The relative responses of the signals of the dosimeter elements gained during the tests according to 9.4, 9.5, and 9.6 shall be used. All radiation qualities listed in 9.4.1.2, 9.4.2.2, 9.4.3.2, 9.5.2.2, 9.6.2.2, 9.6.3.2, and 9.6.4.2 (depending on the type of dosimeter) and all angles of incidence from 0° up to the maximum rated angle, at least for $\pm 45^\circ$ and $\pm 60^\circ$, shall be taken into account. In case the dosimeter 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 dosimeter 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 9.4, 9.5, and 9.6: The indicated value G_K evaluated by the dosimetry system shall be compared to the corresponding indicated value $f(S_{g,K})$ calculated using the signals $S_{g,K}$ of the $g = 1..b$ detector elements and the evaluation algorithm. The values have to be equal, otherwise the manufacturer shall deliver the correct function $f(S_g)$ for the evaluation of the indicated value.

8.2.3 Practical test

Mixed irradiations using the two radiation qualities K and L can be simulated by calculating the sum of the signals $S_{g,K} + S_{g,L}$ for each detector element g . From this sum, the indicated value $G_{K+L} = f(S_{g,K} + S_{g,L})$ for the mixed irradiation condition K+L with the conventional quantity dose value $C_{K+L} = C_K + C_L$ shall be calculated. The indicated value $G_{K+L} = f(S_{g,K} + S_{g,L})$ shall be determined for any possible combination of two radiation qualities K and L with different energy and angle of incidence within the rate range. For every combination of K and L, the ratio of C_K to C_L shall take the following values: 1:9, 2:8, .. up to 9:1 (nine different ratios). The total dose shall be within the standard test conditions, see line 5 of Table 2.

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

EXAMPLE: The rated range goes for photons from 33 keV up to 1,25 MeV and from 0° up to ± 60° and for betas from 0,24 MeV up to 0,8 MeV and from 0° up to ± 60°. According to 9.4.1.2 and 9.6.2.2 nine photon radiation qualities and two beta radiation qualities are involved. In addition, 17 different angles of incidence have to be considered: 0°, 45°, and 60°, the latter four from four different directions (up, down, left, right) as the dosimeter badge is assumed not to be symmetrical in any direction. In summary, (9+2) energies times 17 angles of incidence result in 99 contributions of different radiation qualities. The combination of each contribution with each other leads to $99 \times 98/2 = 4\,851$ combinations. 4 851 combinations times 9 dose ratios result in 43 659 types of signals to get the indicated value.

8.3 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, $r_{\min,K} \dots r_{\max,K}$ and $r_{\min,L} \dots r_{\max,L}$, shall be combined to the weighted limits

for the response values $r_{\min,w} = \frac{r_{\min,K} \times C_K + r_{\min,L} \times C_L}{C_K + C_L}$ and $r_{\max,w} = \frac{r_{\max,K} \times C_K + r_{\max,L} \times C_L}{C_K + C_L}$.

NOTE This is especially relevant if neutron measurements are involved.

In that case the requirement of 8.1 is considered to be met.

9 Radiation performance requirements and tests

9.1 General

All influence quantities dealt with in this clause are regarded as of type F. One possible method to determine the variation of the relative response for radiation energy and angle of radiation incidence is given in Annex D.

The tests are performed for all radiation types the dosimeter is intended to measure. Additionally, the effect of the other types of radiation on the measurement results shall be stated by the manufacturer (see 6.7). If the usage in neutron or beta radiation fields is not excluded in the instruction manual, requirements from 9.5.2.1, 9.6.2.1, 9.6.3.1 or 9.6.4.1 apply.

NOTE 1 The requirements for the influence quantity radiation energy and angle of radiation incidence are given with respect to the reference response R_0 under reference conditions (reference radiation and 0° radiation incidence, reference dose and/or dose rate and all the other reference conditions as given in Table 2). The possible reference radiations can be found for photon radiation in Table 1 of ISO 4037-1:2019, for beta radiation in Table 1 of ISO 6980-1:2023 and for neutron radiation in Table 1 of ISO 8529-1:2021.

The most used reference radiations are given in Table 2, but especially for neutron dosimeters it can be necessary to choose other radiations as reference radiation to comply with the requirements for this influence quantity, even an energy value can be chosen as reference condition for which no physical radiation is available. In that case this (virtual) reference radiation is realized by an available reference radiation and the deviation of the response to the (virtual) reference radiation.

NOTE 2 For high dose photon rates it may be suitable for the testing laboratory to use X-ray qualities or S-Co instead of S-Cs and apply a corresponding correction.

9.2 Consideration of the uncertainty of the conventional quantity value

The expanded relative uncertainty, U_{rel} , of the conventional quantity value of the dose or dose rate of the reference field, shall be less than 8 % = 0,08 at a 95 % coverage interval and shall be taken into account. The testing laboratory shall determine U_{rel} according to ISO/IEC Guide 98-3:2008.

Any requirement needing the use of radiation is considered to be given for $U_{rel} = 0$. For $U_{rel} > 0$, the allowed variation of the relative response shall be enlarged by U_{rel} . If several tests are to be performed with the same radiation quality, for example, the test for the constancy of the response, only the uncertainty of the ratio of the actual value and the reference value of the dose (rate) shall be considered. In case of other requirements, the consideration is mentioned in the respective method of test.

9.3 Constancy of the dose response, dose rate dependence and statistical fluctuations

9.3.1 General

The tests for constancy of dose response, dose rate dependence and statistical fluctuations are performed using the same measurement data.

If the method of detection is different for photon, beta and neutron radiation or for specific energy ranges of these radiations, this requirement shall be tested separately for all types of radiation.

If the manufacturer can show that the technical design of the dosimeter ensures the fulfilment of the requirements on constancy of the dose response for a large range of dose values, then the number of tests can be reduced. Only tests with different dose rates are then required.

9.3.2 Requirements

- Under standard test conditions, with the calibration controls adjusted according to the manufacturer's instructions, the variation of the relative response due to the non-constancy of the dose response shall not exceed the values listed in Table 3 through Table 6 line 1 over the whole of the effective range of measurement for either X, gamma, neutron or beta reference radiations chosen. The dose rate shall be varied over the whole range of dose rate specified by the manufacturer for dose measurements. The dose rate acts as an influence quantity here.
- The statistical fluctuations of the indication measured as coefficient of variation shall fulfil the requirements given in Table 3 to Table 6 lines 2 and 3.
- For photon dosimeters measuring $H_p(10)$ from X and gamma radiations the difference between the indicated background dose, G_{nat} , and the conventional quantity value of the background dose, H_{nat} , shall not exceed H_0 for the stated measuring time t_{max} .

NOTE This implies for photon dosimeters measuring $H_p(10)$ from X and gamma radiations that the difference between the indicated background doses, G_{nat} , for different dosimeters samples does not exceed 2 times H_0 for the stated measuring time t_{max} .

**Table 3 – Radiation characteristics of $H_p(0,07)$ dosimeters
for X, gamma and beta radiation**

Line	Characteristic under test or influence quantity	Minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
1	Variation of the relative response due to dose and dose rate	1 mSv to 3 Sv and $5 \mu\text{Sv h}^{-1}$ to 1 Sv h^{-1} ^{a)} for personal dose equivalent	–13 % to +18 % ^{b)} dosimeter	9.3
2	Statistical fluctuation, v : dose $H_p(0,07)$ for X, gamma and beta radiation	$H_0 \leq H < 1 \text{ mSv}$ $1 \text{ mSv} \leq H < 11 \text{ mSv}$ $11 \text{ mSv} \leq H$	15 % $(16 - H / (1 \text{ mSv})) \%$ 5 %	9.3
3	Statistical fluctuation, v : dose rate $\dot{H}_p(0,07)$ for X, gamma and beta radiation	$\dot{H}_0 \leq \dot{H} < 100 \mu\text{Sv h}^{-1}$ $100 \mu\text{Sv h}^{-1} \leq \dot{H} < 600 \mu\text{Sv h}^{-1}$ $\dot{H} \geq 600 \mu\text{Sv h}^{-1}$	20 % $(21 - \dot{H} / (100 \mu\text{Sv h}^{-1})) \%$ 15 %	9.3
4	X and gamma radiation energy and angle of incidence	30 keV to 1,25 MeV or 20 keV to 150 keV and 0° to 60° from reference direction	–29 % to +67 % ^{c)}	9.4.1
5	Mean beta radiation energy and angle of incidence	For extremity dosimeters: 0,8 MeV and 0° to $\pm 60^\circ$ from reference direction and a mandatory test at 0,24 MeV and 0° to $\pm 60^\circ$ from reference direction For whole body dosimeters: 0,8 MeV and 0° to $\pm 45^\circ$ from reference direction	–29 % to +67 % ^{c)} Compliance at 0.24 MeV is not required but results shall be stated	9.6.2
6	Overload	10 times maximum range not more than 20 Sv or 10 Sv h^{-1}	Dose overload: indicate overload Dose rate overload: indicate overload until dose reset	9.9
7	Response time for dose rate indication and alarm functions	$\dot{H}_p(0,07) \geq 10 \text{ mSv h}^{-1}$ and 10 s maximum waiting time	–13 % to +18 % for the indication after 20 s and any delay of more than 2 s in the alarm responding shall not result in the receipt of a dose in excess of $100 \mu\text{Sv}$	9.10.2
8	Accuracy of alarm set to H_a or $\dot{H}_a$	$H_a \geq$ maximum value of the second least significant order of magnitude $\dot{H}_a \geq$ maximum value of the second least significant order of magnitude	$0,87 (1 - U_{\text{rel}}) \leq H_a / H_{a,c}$ $\leq 1,18 (1 + U_{\text{rel}})$ ^{d)} $\dot{H} \leq (1 - 2 v_{\text{max}}) \dot{H}_a$: Alarm active not more than 5 % of time $\dot{H} \geq (1 + 2 v_{\text{max}}) \dot{H}_a$: Alarm active for at least 95 % of time	9.10.3 9.10.4
9	Effects of radiation not intended to be measured	—	Response to be stated by the manufacturer	6.7

^{a)} Minimum dose rate value as low as reasonably achievable.

^{b)} This variation of the relative response is additional to the uncertainty in the determination of the ratio of the actual value and the reference value of the conventional quantity value of the dose (rate).

^{c)} This variation of the relative response is additional to the uncertainty in the determination of the conventional quantity value of the dose (rate).

^{d)} $H_{a,c}$ is the conventional quantity value of the dose at which the alarm occurs.

Table 4 – Radiation characteristics of $H_p(3)$ dosimeters for X, gamma and beta radiation

Line	Characteristic under test or influence quantity	Minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
1	Variation of the relative response due to dose and dose rate	300 μSv to 1 Sv and 0,1 $\mu\text{Sv h}^{-1}$ to 1 Sv h^{-1} ^{a)} for personal dose equivalent	–13 % to +18 % ^{b)} dosimeter	9.3
2	Statistical fluctuation, v : dose $H_p(3)$	$H_0 \leq H < 0,3 \text{ mSv}$ $0,3 \text{ mSv} \leq H < 3,3 \text{ mSv}$ $3,3 \text{ mSv} \leq H$	15 % $(16 - H / (0,3 \text{ mSv})) \%$ 5 %	9.3
3	Statistical fluctuation, v : dose rate $\dot{H}_p(3)$	$\dot{H}_0 \leq \dot{H} < 10 \mu\text{Sv h}^{-1}$ $10 \mu\text{Sv h}^{-1} \leq \dot{H} < 60 \mu\text{Sv h}^{-1}$ $\dot{H} \geq 60 \mu\text{Sv h}^{-1}$	20 % $(21 - \dot{H} / (10 \mu\text{Sv h}^{-1})) \%$ 15 %	9.3
4	X and gamma radiation energy and angle of incidence	30 keV to 250 keV and 0° to 60° from reference direction under consideration	–29 % to +67 % ^{c)}	9.4.2
5	Mean beta radiation energy and angle of incidence	0,8 MeV and 0° to 60° from reference direction	–29 % to +67 % ^{c)} only if dosimeter is specified for beta radiation, otherwise compliance is not required but results shall be stated (see 9.6.1)	9.6.3
6	Mean beta radiation energy and angle of incidence	0,24 MeV and 0°	Indicated value not larger than 10 % of irradiated $H_p(0,07)$ dose only if dosimeter is specified for beta radiation, otherwise compliance is not required but results shall be stated (see 9.6.1)	9.6.3
7	As in line 4 to 6 but new reference direction opposite to that one used	See line 4 to 6, if no statement concerning wrong orientation is given by the manufacturer	See line 4 to 6, if no statement concerning wrong orientation is given by the manufacturer	7.7
8	Overload	10 times maximum range not more than 20 Sv or 10 Sv h^{-1}	Dose overload: indicate overload Dose rate overload: indicate overload until dose reset	9.9
9	Response time for dose rate indication and alarm functions	$\dot{H}_p(3) \geq 1 \text{ mSv h}^{-1}$ and 10 s maximum waiting time	–13 % to +18 % for the indication after 20 s and any delay of more than 2 s in the alarm responding shall not result in the receipt of a dose in excess of 10 μSv	9.10.2
10	Accuracy of alarm set to H_a or $\dot{H}_a$	$H_a \geq$ maximum value of the second least significant order of magnitude $\dot{H}_a \geq$ maximum value of the second least significant order of magnitude	$0,87 (1 - U_{\text{rel}}) \leq H_a / H_{a,c} \leq 1,18 (1 + U_{\text{rel}})$ ^{d)} $\dot{H} \leq (1 - 2 v_{\text{max}}) \dot{H}_a$: Alarm active not more than 5 % of time $\dot{H} \geq (1 + 2 v_{\text{max}}) \dot{H}_a$: Alarm active for at least 95 % of time	9.10.3 9.10.4
11	Effects of radiation not intended to be measured	—	Response to be stated by the manufacturer	6.7

Line	Characteristic under test or influence quantity	Minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
12	Response due to natural background radiation	—	Deviation of the indication during $t_{\max}$ from the natural background less than H_0	9.3.5
a) Minimum dose rate value as low as reasonably achievable. b) This variation of the relative response is additional to the uncertainty in the determination of the ratio of the actual value and the reference value of the conventional quantity value of the dose (rate). c) This variation of the relative response is additional to the uncertainty in the determination of the conventional quantity value of the dose (rate). d) $H_{a,c}$ is the conventional quantity value of the dose at which the alarm occurs.				

Table 5 – Radiation characteristics of $H_p(10)$ dosimeters for X and gamma radiation

Line	Characteristic under test or influence quantity	Minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
1	Variation of the relative response due to dose and dose rate	100 μSv to 1 Sv and 0,5 $\mu\text{Sv h}^{-1}$ to 1 Sv h^{-1} a)	–13 % to +18 % b)	9.3
2	Statistical fluctuation, v : dose $H_p(10)$	$H_0 \leq H < 0,1 \text{ mSv}$ $0,1 \text{ mSv} \leq H < 1,1 \text{ mSv}$ $1,1 \text{ mSv} \leq H$	15 % (16 – $H / (0,1 \text{ mSv})$) % 5 %	9.3
3	Statistical fluctuation, v : dose rate $\dot{H}_p(10)$	$\dot{H}_0 \leq \dot{H} < 10 \mu\text{Sv h}^{-1}$ $10 \mu\text{Sv h}^{-1} \leq \dot{H} < 60 \mu\text{Sv h}^{-1}$ $\dot{H} \geq 60 \mu\text{Sv h}^{-1}$	20 % (21 – $\dot{H} / (10 \mu\text{Sv h}^{-1})$) % 15 %	9.3
4	Radiation energy and angle of incidence	80 keV to 1,25 MeV or 20 keV to 150 keV and 0° to 60° from reference direction under consideration	–29 % to +67 % c)	9.4.3
5	Mean beta radiation energy and angle of incidence	0,8 MeV and 0°	Indicated value not larger than 10 % of irradiated $H_p(0,07)$ dose	9.6.4
6	As in line 4 but new reference direction opposite to that one used	See line 4, if no statement concerning wrong orientation is given by the manufacturer	See line 4, if no statement concerning wrong orientation is given by the manufacturer	7.7
7	Overload	10 times maximum range not more than 20 Sv or 10 Sv h^{-1}	Dose overload: indicate overload Dose rate overload: indicate overload until dose reset	9.9
8	Response time for dose rate indication and alarm functions	$\dot{H}_p(10) \geq 1 \text{ mSv h}^{-1}$ and 10 s maximum waiting time	–13 % to +18 % for the indication after 10 s and any delay of more than 2 s in the alarm responding shall not result in the receipt of a dose in excess of 10 μSv	9.10.2

Line	Characteristic under test or influence quantity	Minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
9	Accuracy of alarm set to H_a or $\dot{H}_a$	$H_a \geq$ maximum value of the second least significant order of magnitude $\dot{H}_a \geq$ maximum value of the second least significant order of magnitude	$0,87 (1 - U_{rel}) \leq H_a / H_{a,c} \leq 1,18 (1 + U_{rel})$ ^{d)} $\dot{H} \leq (1 - 2 v_{max}) \dot{H}_a$: Alarm active not more than 5 % of time $\dot{H} \geq (1 + 2 v_{max}) \dot{H}_a$: Alarm active for at least 95 % of time	9.10.3 9.10.4
10	Effects of radiation not intended to be measured	—	Response to be stated by the manufacturer	6.7
11	Response due to natural background radiation	—	Deviation of the indication during t_{max} from the natural background less than H_0	9.3.5
a) Minimum dose rate value as low as reasonably achievable. b) This variation of the relative response is additional to the uncertainty in the determination of the ratio of the actual value and the reference value of the conventional quantity value of the dose (rate). c) This variation of the relative response is additional to the uncertainty in the determination of the conventional quantity value of the dose (rate). d) $H_{a,c}$ is the conventional quantity value of the dose at which the alarm occurs.				

Table 6 – Radiation characteristics of $H_p(10)$ dosimeters for neutron radiation

Line	Characteristic under test or influence quantity	Minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
1	Variation of the relative response due to dose and dose rate	100 μ Sv to 1 Sv and 5 μ Sv h ⁻¹ to 1 Sv h ⁻¹ ^{a)} for personal dose equivalent	-20 % to +33 % $\leq$ 5 mSv -20 % to +33 % $>$ 5 mSv ^{b)} dosimeter	9.3
2	Statistical fluctuation, v : dose	$H_0 \leq H < 51 H_0$ $H \geq 51 H_0$	$(25,4 - H / (2,5 H_0))$ % 5 %	9.3
3	Statistical fluctuation, v : dose rate for alarm functions	$\dot{H}_0 \leq \dot{H} < 1 \text{ mSv h}^{-1}$ $1 \text{ mSv h}^{-1} \leq \dot{H} < 6 \text{ mSv h}^{-1}$ $\dot{H} \geq 6 \text{ mSv h}^{-1}$	20 % $(21 - \dot{H} / (1 \text{ mSv h}^{-1}))$ % 15 %	9.3
4	Radiation energy and angle of incidence	0,025 eV to 100 keV plus 100 keV to 10 MeV Range extension: above 10 MeV and 0° to 60° from reference direction under consideration	-60 % to +700 % ^{c)} -60 % to +100 % ^{c)} -60 % to +100 % ^{c)}	9.5.2
5	As in line 4 but new reference direction opposite to that one used	See line 4, if no statement concerning wrong orientation is given by the manufacturer	See line 4, if no statement concerning wrong orientation is given by the manufacturer	7.7
6	Overload	10 times maximum range not more than 20 Sv or 10 Sv h ⁻¹	Dose overload: indicate overload Dose rate overload: indicate overload until dose reset	9.9

Line	Characteristic under test or influence quantity	Minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
7	Response time for dose rate indication and alarm functions	$\dot{H}_p(10) \geq 10 \text{ mSv h}^{-1}$	–17 % to +25 % for the indication after 10 s and any delay of more than 2 s in the alarm responding shall not result in the receipt of a dose in excess of 500 μSv	9.10.2
8	Accuracy of alarm set to H_a or $\dot{H}_a$	$H_a \geq$ maximum value of the second least significant order of magnitude $\dot{H}_a \geq$ maximum value of the second least significant order of magnitude	$0,87 (1 - U_{\text{rel}}) \leq H_a / H_{a,c} \leq 1,18 (1 + U_{\text{rel}})$ ^{d)} $\dot{H} \leq (1 - 2 v_{\text{max}}) \dot{H}_a$: Alarm active not more than 5 % of time $\dot{H} \geq (1 + 2 v_{\text{max}}) \dot{H}_a$: Alarm active for at least 95 % of time	9.10.3 9.10.4
9	Effects of radiation not intended to be measured	—	Response to be stated by the manufacturer	6.7

a) Minimum dose rate value as low as reasonably achievable.

b) This variation of the relative response is additional to the uncertainty in the determination of the ratio of the actual value and the reference value of the conventional quantity value of the dose (rate).

c) This variation of the relative response is additional to the uncertainty in the determination of the conventional quantity value of the dose (rate).

d) $H_{a,c}$ is the conventional quantity value of the dose at which the alarm occurs.

9.3.3 Method of test using sources

a) Source to be used

For the purpose of this test, the conventional quantity value of the personal dose (rate) at the point of test shall be known. The tests shall be performed with reference sources as given in Table 2 of appropriate activity, for example, ^{137}Cs for photon radiation, $^{241}\text{Am-Be}$ for neutron radiation and $^{90}\text{Sr}/^{90}\text{Y}$ for beta radiation, irradiating the dosimeter on the required phantom (see 7.5) in the reference direction. The dose rate shall be varied over the whole range of dose rates specified by the manufacturer for dose measurements.

If this test cannot be performed on the required phantom (see 7.5), for example, because the required high dose rate cannot be produced at a distance where the entire phantom is irradiated, then the test can also be performed free in air at shorter distances if a correction factor for irradiating free in air instead of on the phantom is applied. This correction factor is specific for the dosimeter under test and the radiation quality used and shall therefore be determined specifically.

Another option, if the needed dose rates cannot be achieved by ^{137}Cs , is to use another radiation quality, e.g. X-rays, for the test and apply a correction factor for the difference in response with respect to the reference energy.

NOTE For dosimeters using more than one detector and special algorithms the correction for the missing phantom might be dose rate dependent.

b) Tests to be performed

The tests shall be performed separately with photon radiation (for example, ^{137}Cs), with neutron radiation (for example, $^{241}\text{Am-Be}$) and with beta radiation (for example, $^{90}\text{Sr}/^{90}\text{Y}$).

The response shall be measured for at least three dose values in each order of magnitude of the effective range of measurement of dose. These shall be at approximately each limit of the order of magnitudes included in the measuring range, at 30 % of each full order of magnitude, at the limits of the measuring range and in the vicinity of range changes (if known).

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

At the different dose values, different dose rate values covered by the rated range of dose rate shall be applied as well. In total, n repeated measurements at each of the w dose values shall be performed, depending on the effective range of measurement of dose. From these measurements the w response values can be calculated from which the variation of the relative response due to the non-constancy of the response may be determined.

9.3.4 Interpretation of the results of the test using sources

Determine the mean value and the coefficient of variation of the n values of the indication for each of the w dose values.

Using the w mean values, the variation of the relative response due to the non-constancy of the response shall not exceed the range listed in Table 3 to Table 6 line 1. Also, using the w values of the coefficients of variation and the values of c_1 and c_2 given in Table 7, show that:

- for $w - 2$ dose values the coefficients of variation are less than c_1 times the limits given in Table 3 to Table 6, 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 Table 3 to Table 6.

In that case, the requirements a) and b) of 9.3.2 can be considered to be met.

NOTE 1 The value of c_1 is always smaller than that of c_2 .

NOTE 2 This method ensures that the probability of passing the test is independent of the number w of dose values at which the test is performed. Without applying the factors c_1 and c_2 the probability of passing the test decreases with increasing number w of dose values at which the tests are performed.

NOTE 3 The reasons for the test procedure are given in Brunzendorf and Behrens, see Bibliography.

Table 7 – 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

9.3.5 Method of test for photon dosimeters using natural radiation

Since the response of the dosimeters with respect to natural radiation or the intrinsic background may be different between different samples, the following test shall be performed with at least 5 different samples. The response of the dosimeters may depend on the direction of the natural radiation. Therefore, the test shall be performed in three orthogonal orientations of the dosimeter.

- Simple test: Place these dosimeter on the required phantom (see 7.5) for at least one week (t_{env}) in a normal laboratory environment and assume as a first estimate a background dose rate $\dot{H}_{\text{nat}}$ of $2 \mu\text{Sv d}^{-1}$, if no other information is available. Determine the instrument's accumulated dose $G_{\text{i,nat}}$ for the time t_{env} (see also 6.8). Calculate the expected dose value from the assumed dose rate due to natural environmental radiation $H_{\text{nat}} = 2 \mu\text{Sv d}^{-1} \times t_{\text{env}}$.
- Refined test: This refined test is only necessary if the simple test does not show compliance with the requirements, see 9.3.6. Place the dosimeter on the required phantom (see 7.5) for at least $0,95 \times t_{\text{max}}$ (t_{env}) in an environment where the mean background dose rate $\dot{H}_{\text{nat}}$ is known. This shall be at a standard field station where the dose rates have been measured with reference instruments which are traceable to national standards. Determine the accumulated dose G_{nat} for time t_{env} (see also 6.8). Calculate the expected dose value from the known dose rate due to natural environmental radiation: $H_{\text{nat}} = \dot{H}_{\text{nat}} \times t_{\text{env}}$.

9.3.6 Interpretation of the results of the test using natural radiation

If the inequality

$$\frac{|G_{\text{nat}} - H_{\text{nat}}|}{t_{\text{env}}} \times t_{\text{max}} \leq H_0$$

is valid for all tested dosimeters, the requirement of 9.3.2 c) can be considered to be met.

NOTE 1 This inequation can also be used to fix (new) values for H_0 and t_{max} .

NOTE 2 This will limit the difference in indication of two samples to less than 2 times H_0 after a time of t_{max} .

NOTE 3 The product variation is taken care of by using at least 5 samples.

9.4 Variation of the response due to photon radiation energy and angle of incidence

9.4.1 Measurement quantity $H_p(0,07)$ or $\dot{H}_p(0,07)$

9.4.1.1 Requirements

The relative response due to radiation energy and angle of radiation incidence for photon radiation within the rated range of use shall be within the interval stated in Table 3 line 4. The minimum rated range of use covers the values given in Table 3, line 4 column 3. If the methods of detection are different for specific dose (rate) ranges, this requirement shall be tested separately for all these ranges.

All indicated dose values shall be corrected for non-constant response and for the effect of the influence quantity dose rate on dose measurements.

9.4.1.2 Method of test

For this test, the dosimeter shall be placed on the required phantom (see 7.5). The photon radiation qualities specified in ISO 4037-1, ISO 4037-2, ISO 4037-3, ISO 4037-4 shall be used. The narrow spectrum series is preferred. The selection of the radiation qualities should be done in accordance with Annex D.

The response values shall be measured for angles of incidence of $\alpha = 0^\circ$, $\alpha = \pm 45^\circ$ and $\alpha = \pm 60^\circ$ and if the rated range of use exceeds 0° to $\pm 60^\circ$, $\alpha = \pm \alpha_{\max}$. These measurements shall be performed in two perpendicular planes containing the reference direction through the reference point of the dosimeter.

NOTE 1 The maximum angle of irradiation incidence $\pm \alpha_{\max}$ is limited to $\pm 75^\circ$ for $H_p(0,07)$ on the slab phantom due to the definition of the measuring quantity.

NOTE 2 According to ISO 4037-1 and ISO 4037-3, typical $\dot{H}_p(0,07)$ dose rates of 1 mSv h^{-1} to 10 mSv h^{-1} can be produced for the narrow spectrum series at a distance of 1 m from the focal spot of the X-ray tube operating at 1 mA.

9.4.1.3 Interpretation of the results

All the relative response values due to photon radiation energy and angle of incidence shall be within the limits stated in Table 3 line 4. In that case, the requirements of 9.4.1.1 can be considered to be met.

9.4.2 Measurement quantity $H_p(3)$ or $\dot{H}_p(3)$

9.4.2.1 Requirements

The relative response due to radiation energy and angle of radiation incidence for photon radiation within the rated range of use shall be within the interval stated in Table 4 line 4. The minimum rated range of use covers the values given in Table 4 line 4 column 3.

The maximum angle of irradiation incidence $\pm \alpha_{\max}$ is limited to $\pm 90^\circ$ due to the definition of the measuring quantity.

If the methods of detection are different for specific dose (rate) ranges, this requirement shall be tested separately for all these ranges.

All indicated dose values shall be corrected for non-constant response and for the effect of the influence quantity dose rate on dose measurements.

9.4.2.2 Method of test

For this test, the dosimeter shall be placed on the required phantom (see 7.5). The photon radiation qualities specified in ISO 4037-1, ISO 4037-2, ISO 4037-3, ISO 4037-4 shall be used.

The narrow spectrum series is preferred. The selection of the radiation qualities should be done in accordance with Annex D.

The response values shall be measured for angles of incidence of $\alpha = 0^\circ$, $\alpha = \pm 45^\circ$ and $\alpha = \pm 60^\circ$ and if the rated range of use exceeds 0° to $\pm 60^\circ$, $\alpha = \pm \alpha_{\max}$. These measurements shall be performed in two perpendicular planes containing the reference direction through the reference point of the dosimeter.

9.4.2.3 Interpretation of the results

All the relative response values due to photon radiation energy and angle of incidence shall be within the limits stated in Table 4 line 4 for all energies. In that case, the requirements of 9.4.2.1 can be considered to be met.

9.4.3 Measurement quantity $H_p(10)$ or $\dot{H}_p(10)$

9.4.3.1 Requirements

The relative response due to radiation energy and angle of radiation incidence for photon radiation within the rated range of use shall be within the interval stated in Table 5 line 4. The minimum rated range of use covers at least one of the two energy ranges given in Table 5 line 4 column 3.

The maximum angle of irradiation incidence $\pm \alpha_{\max}$ is limited to $\pm 75^\circ$ due to the definition of the measuring quantity.

All indicated dose values shall be corrected for non-constant response and, if necessary, for the effect of the influence quantity dose rate on dose measurements.

NOTE The two minimum rated ranges reflect the two main workplace conditions. The minimum rated range of use from 80 keV to 1,25 MeV is for workplaces where gamma sources are used, e.g., in industry, and the minimum rated range of use from 20 keV to 150 keV is for workplaces where X-rays are used, e.g., in medical diagnostic radiology. Both ranges can be extended until in the extreme case the rated range of use covers all energies from 10 keV to 7 MeV.

9.4.3.2 Method of test

For this test the dosimeter shall be placed on the ISO water slab phantom. The photon radiation qualities specified in ISO 4037-1, ISO 4037-2, ISO 4037-3, ISO 4037-4 shall be used. The narrow spectrum series is preferred. Their mean energy should be chosen in accordance with Annex D.

The response values shall be measured for angles of incidence of $\alpha = 0^\circ$, $\alpha = \pm 45^\circ$ and $\alpha = \pm 60^\circ$ and if the rated range of use exceeds 0° to $\pm 60^\circ$, $\alpha = \pm \alpha_{\max}$. These measurements shall be performed in two perpendicular planes containing the reference direction through the reference point of the dosimeter.

NOTE According to ISO 4037-1 and ISO 4037-3, typical $\dot{H}_p(10)$ dose rates of $0,1 \text{ mSv h}^{-1}$ to 1 mSv h^{-1} can be produced for the narrow spectrum series at a distance of 2,5 m from the focal spot of the X-ray tube operating at 1 mA.

9.4.3.3 Interpretation of the results

All the relative response values due to photon radiation energy and angle of incidence shall be within the limits stated in Table 5 line 4. In this case, the requirements of 9.4.3.1 can be considered to be met.

9.5 Variation of the response due to neutron radiation energy and angle of incidence

9.5.1 General

The tests given here have to be performed if the dosimeter is intended to measure neutron radiation otherwise the influence of neutron radiation on the indication should be given by the manufacturer and checked at 0° angle of incidence (see 6.7).

9.5.2 Measurement quantity $H_p(10)$ or $\dot{H}_p(10)$

9.5.2.1 Requirements

The relative response due to radiation energy and angle of radiation incidence for neutron radiation within the rated range of use shall be within the interval stated in Table 6 line 4. The minimum rated range of use covers the values given in Table 6 line 4 column 3.

The maximum angle of irradiation incidence $\pm\alpha_{\max}$ is limited to $\pm 75^\circ$ due to the definition of the measuring quantity.

If the methods of detection are different for specific dose (rate) ranges, this requirement shall be tested separately for all these ranges.

All indicated dose values shall be corrected for non-constant response and, if necessary, for the effect of the influence quantity dose rate on dose measurements.

9.5.2.2 Method of test

For this test, the dosimeter shall be placed on the ISO water slab phantom. The neutron radiation qualities specified in ISO 8529-1, ISO 8529-2, ISO 8529-3 and ISO 12789-1, ISO 12789-2 shall be used.

The following energies shall be used, if included in the rated energy range, and the results shall be documented in the manual:

- a) one mainly thermal field with contribution of thermal neutrons to personal dose greater than 50 %
- b) 144 keV or 250 keV;
- c) 565 keV;
- d) 1,2 MeV;
- e) 5 MeV;
- f) bare ^{252}Cf ;
- g) AmBe;
- h) 14,8 MeV;
- i) 19 MeV (if specified energy range includes 20 MeV).

NOTE 1 Using these data the user can decide whether a dosimeter is suitable for his workplace and whether a calibration normalized to bare ^{252}Cf , ^{252}Cf (mod., D_2O) or AmBe is applicable.

In addition, it is recommended to state the response to standardized simulated workplace neutron field sources and to ^{252}Cf (mod., D_2O). By agreement between the manufacturer and the customer, simulated workplace neutron fields shall be selected in accordance with the field encountered at the workplace where the device will be used.

The response values shall be measured for angles of incidence of $\alpha = 0^\circ$, $\alpha = \pm 30^\circ$ and $\alpha = \pm 60^\circ$ and if the rated range of use exceeds 0° to $\pm 60^\circ$, $\alpha = \pm \alpha_{\max}$. These measurements shall be performed in two perpendicular planes containing the reference direction through the reference point of the dosimeter.

NOTE 2 Details of the reference radiations and the calibration procedure are given in ISO 8529-1, ISO 8529-2 and ISO 8529-3. For simulated realistic workplace neutron field sources, see ISO 12789-1 and ISO 12789-2.

9.5.2.3 Interpretation of the results

All the relative response values due to neutron radiation energy and angle of incidence shall be within the limits stated in Table 6 line 4. In that case, the requirements of 9.5.2.1 can be considered to be met.

9.6 Variation of the response due to beta radiation energy and angle of incidence

9.6.1 General

The tests given here have to be performed if the dosimeter is intended to measure beta radiation otherwise the influence of beta radiation on the indication shall be given by the manufacturer and, if the usage in beta radiation fields is not excluded in the instruction manual, the requirements from 9.6.2.1, 9.6.3.1 or 9.6.4.1 apply. Otherwise the indication under 0° angle of incidence should be checked (see 6.7).

9.6.2 Measurement quantity $H_p(0,07)$ or $\dot{H}_p(0,07)$

9.6.2.1 Requirements

The relative response due to radiation energy and angle of radiation incidence for beta radiation within the rated range of use shall be within the interval stated in Table 3 line 5. The minimum rated range of use covers the values given in Table 3 line 5 column 3.

If the methods of detection are different for specific dose (rate) ranges, this requirement shall be tested separately for all these ranges.

All indicated dose values shall be corrected for non-constant response and for the effect of the influence quantity dose rate on dose measurements.

9.6.2.2 Method of test

For this test, the dosimeter shall be placed on the required phantom (see 7.5). The following reference radiation qualities selected from the list of beta reference radiations specified in ISO 6980-1 shall be used:

^{147}Pm	($\bar{E} \approx 0,06 \text{ MeV}$);
^{204}Tl or ^{85}Kr	($\bar{E} \approx 0,24 \text{ MeV}$);
$^{90}\text{Sr}/^{90}\text{Y}$ with 3 mm or 4 mm absorber	($\bar{E} \approx 0,61 \text{ MeV}$ or $\bar{E} \approx 0,54 \text{ MeV}$)
$^{90}\text{Sr}/^{90}\text{Y}$	($\bar{E} \approx 0,8 \text{ MeV}$).

The response values are measured for angles of incidence of $\alpha = 0^\circ$, $\alpha = \pm 45^\circ$ and $\alpha = \pm 60^\circ$ and if the rated range of use exceeds 0° to $\pm 60^\circ$, $\alpha = \pm \alpha_{\max}$. These measurements shall be performed in two perpendicular planes containing the reference direction through the reference point of the dosimeter.

NOTE If a testing laboratory does not have access to the specified reference radiations, they may opt instead to use appropriate alternative reference radiations which are similar in energy, with an appropriate correction factor if needed.

9.6.2.3 Interpretation of the results

All the relative response values due to beta radiation energy and angle of incidence shall be within the limits stated in Table 3 line 5. In this case, the requirements of 9.6.2.1 can be considered to be met.

9.6.3 Measurement quantity $H_p(3)$ or $\dot{H}_p(3)$

9.6.3.1 Requirements

Requirement A: The relative response due to radiation energy and angle of radiation incidence for beta radiation within the rated range of use shall be within the interval stated in Table 4 line 5. The minimum rated range of use covers the values given in Table 4 line 5 column 3.

The maximum angle of irradiation incidence $\pm\alpha_{\max}$ is limited to $\pm 90^\circ$ due to the definition of the measuring quantity.

Requirement B: As the dosimeter is intended to measure $H_p(3)$ or $\dot{H}_p(3)$, the indicated value due to beta radiation with energies up to the energy equivalent of ^{85}Kr shall be less than $0,1 \cdot H_p(0,07)$ or $0,1 \cdot \dot{H}_p(0,07)$ (see line 6 of Table 4 column 3).

If the methods of detection are different for specific dose (rate) ranges, this requirement shall be tested separately for all these ranges.

All indicated dose values shall be corrected for non-constant response and for the effect of the influence quantity dose rate on dose measurements.

9.6.3.2 Method of test

Requirement A: For this test, the dosimeter shall be placed on the required phantom (see 7.5). The following reference radiation qualities selected from the list of beta reference radiations specified in ISO 6980-1 shall be used:

$^{90}\text{Sr}/^{90}\text{Y}$ ($\bar{E} \approx 0,8 \text{ MeV}$);
 $^{106}\text{Ru}/^{106}\text{Rh}$ ($\bar{E} \approx 1,2 \text{ MeV}$).

The response values are measured for angles of incidence of $\alpha = 0^\circ$, $\alpha = \pm 45^\circ$ and $\alpha = \pm 60^\circ$ and if the rated range of use exceeds 0° to $\pm 60^\circ$, $\alpha = \pm\alpha_{\max}$. These measurements shall be performed in two perpendicular planes containing the reference direction through the reference point of the dosimeter.

Requirement B: For this test, the dosimeter shall be placed on the PMMA slab phantom (see 7.5). Expose the dosimeter at 0° angle of radiation incidence to beta reference radiation specified in the ISO 6980 series of the following quality: ^{85}Kr ($\bar{E} \approx 0,24 \text{ MeV}$).

9.6.3.3 Interpretation of the results

Requirement A: All the relative response values due to beta radiation energy and angle of incidence shall be within the limits given in Table 4 line 5. In this case, the requirements of 9.6.3.1 can be considered to be met.

Requirement B: The indicated $H_p(3)$ dose value for ^{85}Kr shall be less than 10 % of the $H_p(0,07)$ dose received.

9.6.4 Measurement quantity $H_p(10)$ or $\dot{H}_p(10)$

9.6.4.1 Requirements

The dosimeter shall be as insensitive as possible to beta radiation because the effective dose, for which $H_p(10)$ is an acceptable estimate, is in general not a suitable quantity for beta radiation.

9.6.4.2 Method of test

For this test, the dosimeter shall be placed on the PMMA slab phantom (see 7.5). Expose the dosimeter at 0° angle of radiation incidence to beta reference radiation specified in the ISO 6980 series of the following quality:

$$^{90}\text{Sr}/^{90}\text{Y} \quad (\bar{E} \approx 0,8 \text{ MeV}).$$

The indicated $H_p(10)$ dose value shall be less than 10 % of the $H_p(0,07)$ dose received.

9.7 Over indication due to radiation incident from the side of an $H_p(10)$, $H_p(3)$ or $H_p(0,07)$ dosimeter

9.7.1 Requirements

If the dosimeter is irradiated free in air from the side ($\alpha_{\max}$ to $180^\circ - \alpha_{\max}$), the indicated value shall not exceed 2 times the indicated value resulting from an irradiation free in air with the same radiation quality from the front (0°). This shall apply to all radiation energies within the rated range of energy.

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

NOTE 2 If $\alpha_{\max} = 60^\circ$, this means an irradiation from 60° to 120° .

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

9.7.2 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 dosimeters shall be irradiated free in air to an ambient dose equivalent of $H^*(10) \approx 3 \text{ mSv}$:

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

Further groups: Irradiations shall be performed at the angle of incidences β corresponding to the "weak points". The azimuthal angle of incidence shall be varied during the irradiation between $\alpha_{\max}$ and $180^\circ - \alpha_{\max}$ in steps of 15° including 90° resulting in the indicated value $\bar{G}_{\alpha_{\max} \text{ to } 180^\circ - \alpha_{\max}}$.

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

NOTE In case of $\alpha_{\max} = 60^\circ$, the irradiation of each badge is performed in three equivalent fractions at 75° , 90° , and 105° .

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

9.7.3 Interpretation of the results

If, for every polar angle examined in accordance with 9.7.2, the inequality $\frac{\bar{G}_{\alpha_{\max \text{ to } 180^\circ - \alpha_{\max}}}}{\bar{G}_{0^\circ}} + U_{\text{com}} \leq 2$ is valid, then the requirement of 9.7.1 is considered to be met. U_{com} is calculated according to formula (B.5), Example 2. This calculation presumes that all dose values used in this test are 100 % correlated. If this is not the case this shall be taken into account when calculating U_{com} , see Annex B.

9.8 Retention of dose reading

9.8.1 General

These requirements shall be tested separately for all dose quantities.

9.8.2 Requirements

- a) At the end of any exposure period, the reading of the dosimeter and that indicated by any associated readout system, if supplied, shall not change by more than ± 2 % or a single change in the least significant digit, whichever is the greatest, over the next 8 h.

The change of the indicated value due to background radiation shall be excluded.

- b) After 24 h from the loss or interruption of the principal voltage supply, the integrated dose measured by the dosimeter, and from any associated readout system, prior to this loss or interruption, shall not change by more than ± 5 %, or a change in the least significant digit, whichever is greater, upon replacement of the principal voltage supply.

9.8.3 Method of test and interpretation of the results

- a) Expose the dosimeter to a source of radiation giving a dose sufficiently high so that any subsequent accumulation due to background radiation can be neglected. Stop the irradiation immediately when the integration period is completed and note the displayed reading. Every hour up to 8 h after the end of the integration period, read the display. None of these eight readings shall differ by more than a least significant digit or by more than ± 2 % compared with the initial reading, whichever is the greatest.
- b) Expose the dosimeter to a source of radiation giving a dose sufficiently high so that any subsequent accumulation due to background radiation can be neglected. Note the displayed reading. The principal batteries shall then be removed from the dosimeter. If the dosimeter needs waiting time before removal of the battery (e.g. for storing data) this shall be given in the instruction manual and applied here. (When the principal battery fails or is removed, the reading may disappear or be replaced by some instruction.) After 24 h, the principal batteries of the dosimeter shall be replaced or recharged. The reading of the dose obtained shall not differ by more than ± 5 % from the last value obtained before the principal batteries were removed, or there shall only be a change in the least significant digit.

9.9 Overload characteristics

9.9.1 General

If the method of detection is different for photon, beta and neutron radiation or for specific energy ranges of these radiations, then this requirement shall be tested separately for all these types of radiation.

9.9.2 Requirements

For dose (rates) greater than that corresponding to the maximum value of the upper order of magnitude of the effective range of measurement and up to ten times the maximum indication, the dosimeter shall be "off-scale" at the higher end of the scale and shall remain so whilst in that radiation field. The manufacturer shall state the time taken for dosimeters that indicate dose rate to return to the appropriate "on-scale" dose rate reading following their irradiation to this overexposure.

For the dose irradiation, the indication shall remain "off-scale" upon removal from the radiation field. For those dosimeters where the dose rate during integration exceeds the measurable rate, an overload condition shall then be indicated and remain until reset of dose. The measurable rates are those for which the requirements of 9.3 are met; the manufacturer shall state the upper limits of such rates. After resetting the dose and overload indication, the dosimeter shall continue to fulfil all requirements of this document.

9.9.3 Method of test and interpretation of the results

9.9.3.1 General

This test shall be performed using an appropriate source.

If the dose (rate) cannot be achieved e.g. on a phantom, procedure and correction as given in 9.3.3a) shall be applied.

If for some types of radiation, for example, neutrons or betas, the required high dose rate fields are not available, this shall be reported. Electrical test methods shall be applied and a theoretical performance analysis shall be performed.

Electrical test may be inadequate for certain detectors. The testing laboratory needs to carefully consider the drawbacks.

9.9.3.2 Dosimeters

The dosimeter shall be irradiated to a dose of 10 times the maximum range value, but no more than 20 Sv. The indication of the dosimeter shall remain at the maximum of the range and an overload indication shall be displayed.

The dosimeter shall be irradiated, for about 10 min, to a dose rate of 10 times the maximum range value, but not more than 10 Sv h^{-1} . An overload indication shall be displayed and remain until the dose is reset.

The dose measurement may be wrong during the overload condition. Therefore, a persistent warning is needed.

9.9.3.3 Dose rate meters

The dosimeter shall be irradiated, for about 10 min, to a dose rate of 10 times the maximum range value, but not more than 10 Sv h^{-1} . The indication of the dosimeter shall remain at the maximum of the range and an overload indication shall be displayed.

Upon removal of this "off-scale" dose rate, the time shall be measured for the indication of the dosimeter to return to an "on-scale" dose rate and recorded in the type test report. This time shall be less than 10 s (20 s for extremity dosimeters).

9.10 Alarm

9.10.1 General

These tests shall be performed separately for $H_p(10)$, $\dot{H}_p(10)$, $H_p(3)$, $\dot{H}_p(3)$, $H_p(0,07)$ and $\dot{H}_p(0,07)$ and for photon, neutron and beta radiation, as appropriate for the dosimeter. All dose (rate) values shall be corrected for non-constant response. If for some types of radiation, for example, neutrons or betas, the required high dose rate fields are not available, this shall be reported, and an electrical test method shall be applied.

If the dose (rate) cannot be achieved e.g. on a phantom, procedure and correction as given in 9.3.3a) shall be applied.

9.10.2 Response time for dose rate indication and alarm

9.10.2.1 Requirements

When the dosimeter is subjected to a step or slow increase or decrease in dose rate of one order of magnitude within the effective range of the dosimeter, the readout shall indicate the new dose rate with an error of less than the range given in line 9 row 3 of Table 3 to Table 6 of the upper dose rate value within 10 s (20 s for extremity dosimeters) after the dosimeter is subjected to the final dose rate. In case of a step increase or decrease the alarm, if set to one half of the upper dose rate value, shall respond within 2 s. These requirements shall apply for changes from background dose rates to upper case dose rate values, which are greater than 1 mSv h⁻¹ for $\dot{H}_p(10)$ from X and gamma radiation and 10 mSv h⁻¹ for $\dot{H}_p(0,07)$ from X, gamma and beta radiation and 10 mSv h⁻¹ for $\dot{H}_p(10)$ from neutron radiation. Alternatively, any delay of more than 2 s in the alarm responding or 10 s in the indication shall not result in the receipt of a dose in excess of 10 µSv for $\dot{H}_p(10)$ from X and gamma radiation and 100 µSv for $\dot{H}_p(0,07)$ from X, gamma and beta radiation and 500 µSv for $\dot{H}_p(10)$ from neutron radiation.

NOTE The response time is valid for the first alarm (audible OR visual OR vibrational).

9.10.2.2 Method of test and interpretation of the results

For this test the dosimeter shall be placed in the irradiation facility in non-irradiating conditions and allowed to stabilize.

The irradiation facility shall then rapidly or slowly be set to irradiating conditions and readings recorded continuously until the dosimeter stabilizes at the new upper dose rate giving the reading $\dot{G}_{high}$. The change of the indication to 87 % (photon or beta dosimeters) or 83 % (neutron dosimeters) of this high reading $\dot{G}_{high}$ shall take less than 10 s (20 s for extremity dosimeters) after the dosimeter is subjected to the final dose rate. In case of a step increase or decrease the alarm, if set to one half of the dose rate reading, 0,5 $\dot{G}_{high}$, shall respond within 2 s.

Next the irradiation facility shall rapidly or slowly be set to non-irradiating conditions. The dosimeter reading shall be below 25 % of the reading $\dot{G}_{high}$ within 10 s (20 s for extremity dosimeters) after the dosimeter is subjected to the final dose rate. In case of a step increase or decrease the alarm, if set to one half of the dose rate reading, 0,5 $\dot{G}_{high}$, shall stop within 2 s. The dose accrued during the delay in the alarm responding shall be measured.