BS EN 61005:2017

BSI Standards Publication

# Radiation protection instrumentation — Neutron ambient dose equivalent (rate) meters (IEC 61005:2014)

bsi.

**National foreword**

This British Standard is the UK implementation of EN 61005:2017. It is derived from IEC 61005:2014. It supersedes BS EN 61005:2004 which is withdrawn.

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

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

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

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


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**Amendments/corrigenda issued since publication**

| Date | Text affected |
|---|---|

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

**EN 61005**

January 2017

ICS 13.280

English Version

# Radiation protection instrumentation - Neutron ambient dose equivalent (rate) meters (IEC 61005:2014 , modified)

Instrumentation pour la radioprotection - Appareils de mesure de l'équivalent de dose ambiant neutron (ou de son débit d'équivalent de dose) (IEC 61005:2014 , modifiée)

Strahlenschutz-Messgeräte - Umgebungsäquivalentdosis(leistungs)-Messgeräte für Neutronenstrahlung (IEC 61005:2014 , modifiziert)

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

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

## European foreword

This document (EN 61005:2017) consists of the text of IEC 61005:2014 prepared by SC 45B “Radiation protection instrumentation” of IEC/TC 45 “Nuclear instrumentation”, together with the common modifications prepared by CLC/TC 45B "Radiation protection instrumentation".

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2017-11-14
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2019-11-14

This document supersedes EN 61005:2004.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

### Endorsement notice

The text of the International Standard IEC 61005:2014 was approved by CENELEC as a European Standard with agreed common modifications.

# Annex ZA
(normative)

## Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| IEC 60050 | Series | International Electrotechnical Vocabulary | - | - |
| IEC 60086-1 | 2011 | Primary batteries - Part 1: General | EN 60086-1 | 2011 [1)] |
| IEC 60086-2 | 2011 | Primary batteries - Part 2: Physical and electrical specifications | EN 60086-2 | 2011 [2)] |
| IEC 60529 | - | Degrees of protection provided by enclosures (IP Code) | EN 60529 | - |
| IEC 61187 | - | Electrical and electronic measuring equipment - Documentation | EN 61187 | - |
| IEC 62706 | - | Radiation protection instrumentation - Environmental, electromagnetic and mechanical performance requirements | - | - |
| ISO 8529-1 | 2001 | Reference neutron radiations - Part 1: Characteristics and methods of production | - | - |
| ISO 8529-2 | 2000 | Reference neutron radiations - Part 2: Calibration fundamentals of radiation protection devices related to the basic quantities characterizing the radiation field | - | - |
| ISO 8529-3 | 1998 | Reference neutron radiations - Part 3: Calibration of area and personal dosimeters and determination of response as a function of energy and angle of incidence | - | - |

[1)] Superseded by EN 60086-1:2015 (IEC 60086-1:2015): DOW=2018-09-01.
[2)] Superseded by EN 60086-2:2016 (IEC 60086-2:2015): DOW=2018-12-03.

| Publication | Year | Title | EN/HD | Year |
|---|---|---|---|---|
| ISO 11929 | 2010 | Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation - Fundamentals and application | - | - |
| ISO 12789-1 | 2008 | Reference radiation fields - Simulated workplace neutron fields - Part 1: Characteristics and methods of production | - | - |
| ISO 12789-2 | 2008 | Reference radiation fields - Simulated workplace neutron fields - Part 2: Calibration fundamentals related to the basic quantities | - | - |

# CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# RADIATION PROTECTION INSTRUMENTATION – NEUTRON AMBIENT DOSE EQUIVALENT (RATE) METERS

## FOREWORD

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International Standard 61005 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

This third edition cancels and replaces the second edition of IEC 61005 issued in 2003 and constitutes a technical revision.

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

a) upper neutron energy of the instruments covered by the standard is increased to 20 MeV;
b) requirement for the variation of the relative response due to neutron energy is modified;
c) a clause for additivity of the indicated value (neutron dose/dose rate) is introduced;
d) a clause and requirement for Monte Carlo calculation of the instrument response are introduced;
e) a clause and requirement for the software for generation of the measured values are introduced;
f) environmental testing methods and requirements are referred to IEC 62706;

g) influence quantities of type S and F are introduced.

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

| FDIS | Report on voting |
|---|---|
| 45B/792/FDIS | 45B/797/RVD |

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

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

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

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

# RADIATION PROTECTION INSTRUMENTATION – NEUTRON AMBIENT DOSE EQUIVALENT (RATE) METERS

## 1 Scope

This International Standard is applicable to assemblies designed to measure the ambient dose equivalent (rate) due to neutron radiation in fields that contain neutrons with energies below 20 MeV, and which comprise at least:

a) a detection assembly, which may, for example, consist of a detector probe for thermal neutrons and an arrangement of neutron moderating and absorbing media surrounding the detector;

b) a measuring assembly with a display for the measured quantity, which may be incorporated into a single assembly with the detector or connected to it by means of a flexible cable.

Instruments with energy range up to 20 MeV are covered by this standard. If the instrument also provides indication of the neutron dose, it should meet the neutron dose requirements stated in this standard.

No tests are specified in this standard for performance requirements of assemblies in pulsed radiation fields. It is understood that an assembly designed to meet this standard may not be suitable for use in such fields.

The object of this standard is to specify requirements for the performance characteristics of neutron ambient dose equivalent (rate) meters, and to prescribe the methods of testing in order to determine compliance with this standard. This standard specifies general characteristics, general test procedures, radiation characteristics, electrical, mechanical, safety and environmental characteristics, and also the identification certificate (see 13.2). Requirements and test procedures are also specified for the alarm performance of the neutron ambient dose equivalent (rate) meters, equipped with alarm provisions.

NOTE The response of ambient dose equivalent (rate) meters for neutrons is energy dependent and may deviate considerably from unity. The response in 〚C〛 workplace field 〚C〛, however, is such that the response deviations in different energy ranges tend to offset each other. Consequently, the response in 〚C〛 workplace field 〚C〛 is generally much closer to unity.

ISO 12789 specifies a list of appropriate broad-spectrum neutron sources that are suitable for the testing of such (rate) meters. For example, simulated workplace neutron fields from ISO 12789 may be specified by agreement between manufacturer and purchaser to be appropriate for testing when the spectral environment is well defined.

## 2 Normative references

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

IEC 60050 (all parts): *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

IEC 60086-1:2011, *Primary batteries – Part 1: General*

IEC 60086-2:2011, *Primary batteries – Part 2: Physical and electrical specifications*

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

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

IEC 62706, *Radiation protection instrumentation – Environmental, electromagnetic and mechanical requirements*

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

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

ISO 8529-3:1998, *Reference neutron radiations – Part 3: Calibration of area and personal dosemeters and determination of response as a function of energy and angle of incidence*

ISO 11929:2010, *Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation – Fundamentals and application*

ISO 12789-1:2008, *Reference radiation fields – Simulated workplace neutron fields – Part 1: Characteristics and methods of production*

ISO 12789-2:2008, *Reference radiation fields – Simulated workplace neutron fields – Part 2: Calibration fundamentals related to basic quantities*

## 3 Terms and definitions, abbreviations and symbols, quantities and units

### 3.1 Terms and definitions

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

NOTE For sentence clarity and text conciseness in this standard the term “neutron ambient dose equivalent (rate) meter” is abbreviated as “neutron dose (rate) meter”. Whenever the term “neutron dose (rate) meter” appears in this standard it is understood that “neutron ambient dose equivalent (rate) meter” is meant.

**3.1.1**
**alarm**
audible, visual, or other signal activated when the instrument reading exceeds a preset value, falls outside of a preset range, when the instrument is unable to function properly (component failure), or when the instrument detects the presence of the source of radiation according to a preset condition

**3.1.2**
**ambient dose equivalent**
$H^*(10)$
dose equivalent at a point in a radiation field that would be produced by the corresponding aligned and expanded field, in the ICRU sphere at a depth of 10 mm on the radius opposing the direction of the aligned field ([2], [5][1])

Note 1 to entry: An instrument that has an isotropic response and is calibrated in terms of $H^*(10)$ will measure $H^*(10)$ in a radiation field that is uniform over the dimensions of the instrument.

1 Numbers in square brackets refer to the Bibliography.

**3.1.3**
**ambient dose equivalent rate**
$H^*(10)$
ratio of $dH^*(10)$ by $dt$, where $dH^*(10)$ is the increment of ambient dose equivalent in the time interval $dt$

$$\dot{H}^*(10) = \frac{dH^*(10)}{dt}$$

**3.1.4**
**background level**
radiation field in which the instrument is intended to operate, including that produced by naturally occurring radioactive material and cosmic radiation

**3.1.5**
**calibration distance**
distance between the reference point of the assembly and the centre of the calibration source

**3.1.6**
**coefficient of variation**
v
ratio of the experimental standard deviation s to the arithmetic mean $\bar{H}$ of a set of n indications $H_j$. It is given by the following formula:

$$v = \frac{s}{\bar{H}} = \frac{1}{\bar{H}} \cdot \sqrt{\frac{1}{n-1} \cdot \sum_{j=1}^{n} (H_j - \bar{H})^2}$$

**3.1.7**
**conventional quantity value**
$H_t$
quantity value attributed by agreement to a quantity for a given purpose

Note 1 to entry: In this standard the quantity is the dose equivalent (rate).

Note 2 to entry: The term “conventional true quantity value” is sometimes used for this concept.

Note 3 to entry: Sometimes a conventional quantity value is an estimate of a true quantity value.

Note 4 to entry: A conventional quantity value is generally accepted as being associated with a suitably small measurement uncertainty, which might be zero.

[SOURCE: VIM:2008, 2.12]

**3.1.8**
**deviation**
$D$
difference between the indicated values for the same value of the measurand of a dose equivalent (rate) meter, when made under reference conditions and when subject to an influence quantity

$$D = H_{\mathrm{i}} - H_{\mathrm{r}}$$

Where

$H_{\mathrm{i}}$ is the indicated value under the effect of an influence quantity, and

$H_{\mathrm{r}}$ is the indicated value under reference conditions.

Note 1 to entry: The deviation can be positive or negative resulting in an increase or a decrease of the indicated value, respectively.

Note 2 to entry: The deviation is of special importance for influence quantities of Type S.

**3.1.9**
**effective range of measurement**
range of values of ambient dose equivalent (rate) over which the performance of the ambient dose equivalent (rate) meter meets the requirements of this standard

**3.1.10**
**indicated value**
$H_i$
value given by the (digital) indication of the dose (rate) meter in units of dose equivalent or dose equivalent rate

**3.1.11**
**influence quantity**
quantity that is not the measurand but that affects the result of the measurement

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

Note 2 to entry: If the effect on the result of a measurement of an influence quantity depends on another influence quantity, these influence quantities are treated as a single one.

[SOURCE: IEC 60050-394:2007,394-40-27]

**3.1.12**
**influence quantity of type F**
influence quantity whose effect on the indicated value is a change in response

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

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

**3.1.13**
**influence quantity of type S**
influence quantity whose effect on the indicated value is a deviation independent of the indicated value

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

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

Note 3 to entry: "S" stands for sum. The indication is the sum of the indication due to radiation and due to the influence quantity, e.g., electromagnetic disturbance.

**3.1.14**
**lower limit of effective range of measurement**
$H_0$ or $(\dot{H}_0)$
the lowest dose (rate) value included in the effective range of measurement

**3.1.15**
**maximum dose equivalent rate for dose (rate) meters**

$\dot{H}_{max}$
dose rate, specified by the manufacturer, below which the effect of the dose rate on the dose rate reading is within specified limits

**3.1.16**
**measured value**
$M$
value that can be obtained from the indicated value $H_i$ by applying the model function for the measurement

Note 1 to entry: The model function is necessary to evaluate the uncertainty of the measured value according to the GUM (see [3]:2008,3.1.6, 3.4.1 and 4.1).

Note 2 to entry: An example of a model function is given herein. It combines the indicated value $H_i$

with the reference calibration factor $N_0$, the correction for non-linear 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:

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

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.

Note 4 to entry: If necessary another model function closer to the design of a certain dose (rate) meter may be used.

Note 5 to entry: With the calibration controls adjusted according to the manufacturer's instructions, the reference calibration factor, the correction for non-linear response and all relative response values are set to one and the deviations are set to zero, these settings cause an uncertainty of measurement which can be determined from the measured variation of the response values and the measured deviations. For a dose (rate) meter tested according to this standard, all these data are available.

**3.1.17**
**〚C〉 minimum 〈C〛 rated range of use**
the smallest range being specified for an influence quantity or instrument parameter over which the dose equivalent (rate) meter shall operate within the specified limits of variation in order to comply with this standard

Note 1 to entry: The 〚C〉 minimum 〈C〛 rated ranges of the influence quantities dealt with in this standard are given in the second column of Tables 2, 4, 5 and 6.

**3.1.18**
**neutron ambient dose equivalent (rate) meter**
assembly intended to measure the ambient dose equivalent dose and/or rate from neutron radiation

**3.1.19**
**neutron dose equivalent response**
$\boldsymbol{R_H}$
ratio, under specified conditions, given by the relation

$$R_H = \frac{R_\Phi}{h_\Phi}$$

Where

$R_\Phi$ is the neutron fluence response (see definition 3.1.22) and

$h_\Phi$ is the neutron fluence-to-dose conversion coefficient (see definition 3.1.23).

**3.1.20**
**neutron fluence**
$\Phi$
quotient of $dN$ by $da$, where $dN$ is the number of neutrons incident on a sphere of cross-sectional area $da$:

$$\Phi = \frac{dN}{da}$$

Note 1 to entry: The unit of neutron fluence is $m^{-2}$.

**3.1.21**
**neutron fluence rate (flux density)**
$\dot{\Phi}$
quotient of $d\Phi$ by $dt$, where $d\Phi$ is the increment of neutron fluence in the time interval $dt$:

$$\dot{\Phi} = \frac{d\Phi}{dt}$$

Note 1 to entry: The unit of neutron fluence rate is $m^{-2} \cdot s^{-1}$.

**3.1.22**
**neutron fluence response**
$\boldsymbol{R_{\Phi}}$
ratio, under specified conditions, given by the relation

$$R_{\Phi} = \frac{M}{\Phi}$$

Where

$M$ is the reading by the instrument under test (dosemeter) for the neutron fluence and

$\Phi$ is the conventional quantity value of the neutron fluence to which the instrument has been exposed.

Note 1 to entry: The unit of neutron fluence response is $m^2$.

**3.1.23**
**neutron fluence-to-ambient dose equivalent conversion coefficient**
$h_{\Phi}$
quotient of the neutron ambient dose equivalent, $H^*(10)$, and the neutron fluence, $\Phi$, at a point in the radiation field, undisturbed by the irradiated object

$$h_{\Phi} = \frac{H^*(10)}{\Phi}$$

Note 1 to entry: The conversion coefficients are given in Annex A.

**3.1.24**
**non-linearity**
variation of the value of the (relative) response with the dose (rate) being measured

**3.1.25**
**point of test of a dose (rate) equivalent meter**
point at which the conventional quantity value is determined and at which the reference point of the dose equivalent (rate) meter is placed for calibration and test purposes

Note 1 to entry: For all tests involving the use of radiation, the reference point of the assembly is placed at the point of test in the orientation indicated by the manufacturer. An exception is the test of variation in response with angle of incidence.

**3.1.26**
**quantity value of ambient dose equivalent (rate)**
best estimate of the true ambient dose equivalent (rate), $H_t^*(10)$, used for calibration of the assembly. This value and its uncertainty are determined from a primary or a secondary standard, or by a reference instrument which has been calibrated against a secondary or a primary standard.

Note 1 to entry: Primary or secondary standards for neutron radiation are usually standardized in terms of fluence (rate). For converting the fluence (rate) to the conventional true value of the ambient dose equivalent (rate), the appropriate fluence to ambient dose equivalent conversion coefficients given in Annex A shall be used.

**3.1.27**
**rated range of use of a dose equivalent (rate) meter**
range of values of an influence quantity or instrument parameter over which the dose equivalent (rate) meter will operate within the specified limits of variation. Its limits are the maximum and minimum rated values

**3.1.28**
**reference direction**
direction in the coordinate system of the dose (rate) meter with respect to which the angle of the direction of radiation incidence is measured in unidirectional fields

[SOURCE: ISO 8529-3:1998, 3.2.7]

**3.1.29**
**reference point of an assembly**
physical or virtual mark or marks on the assembly to be used in order to position it at the test point. This mark is usually either the geometric centre of the detector or its effective centre.

**3.1.30**
**reference response**
$\mathbf{R}_r$
response for a reference value of the quantity to be measured under reference conditions

$$R_{\mathrm{r}} = \frac{H_{\mathrm{r}}}{H_{\mathrm{t}}}$$

Where

$H_{\mathrm{r}}$ is the corresponding indicated value of the quantity to be measured under reference conditions and

$H_{\mathrm{t}}$ is the conventional quantity value (3.1.7) under reference conditions

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

Note 2 to entry: The reference values for the dose (rate) are given in Table 1.

**3.1.31**
**reference standard**
standard generally having the highest metrological quality available at a given location or in a given organization from which measurements made are derived

[SOURCE: IEC 60050-395:2014,395-03-118; IEC 61577-1:2006,3.1.5; IEC 61577-4:2009, 3.1.5]

**3.1.32**
**relative response**
$r$
quotient of the response $R$ (3.1.22) and the reference response $R_{\mathrm{r}}$ (3.1.30)

$$r = \frac{R}{R_{\mathrm{r}}}$$

**3.1.33**
**response of a radiation measuring assembly**
$R$
ratio, under specified conditions, given by the relation

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

where

$H_i$ is the indicated value of the quantity (3.1.10) measured by the instrument under test and

$H_t$ is the conventional quantity value of this quantity (3.1.7).

**3.1.34**
**standard test conditions**
conditions representing the range of values of a set of influence quantities under which a calibration or a determination of response is carried out.

[SOURCE: ISO 4037-3:1999, 3.2.3, modified]

**3.1.35**
**standard test values**
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.

Note 1 to entry: Under standard test conditions, influence quantities and instrument parameters have their standard test values.

### 3.2 Test nomenclature

**3.2.1**
**qualification tests**
tests, which are performed in order to verify that the requirements of a device specification are fulfilled. Qualification tests are subdivided into type tests and routine tests

**3.2.2**
**type tests**
conformity testing on the basis of one or more devices representative of the production

**3.2.3**
**routine tests**
tests to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

**3.2.4**
**acceptance tests**
contractual tests to prove to the customer that the device meets certain conditions of its specification

**3.2.5**
**supplementary tests**
tests intended to provide supplementary information on certain characteristics of the device

### 3.3 Abbreviations and symbols

Abbreviations and symbols are provided in Table 8.

### 3.4 Quantities and units

In this standard, units of the International System (SI) are used[2]. The definitions of radiation quantities are given in IEC 60050-395. The corresponding old units (non-SI) are indicated in brackets.

Nevertheless, the following units may also be used:

– for energy: electron-volt (symbol: eV), 1 eV = 1,602 × $10^{-19}$ J;

– for time: days (symbol: d), hours (symbol: h), minutes (symbol: min).

Multiples and submultiples of SI units will be used, when practicable, according to the SI system.

## 4 General test procedure

### 4.1 Test requirements

All the tests enumerated in the following clauses are to be considered type tests (see 3.2.2). During type tests, all values of influence quantities which are not the subject of the test are fixed within the interval of the standard test conditions.

Nevertheless, some of these tests may, by agreement between manufacturer and purchaser, be considered as acceptance tests.

Reference conditions and standard test conditions are defined in Table 1.

The tests described in this standard may be classified according to whether they are performed under standard test conditions or under other conditions. 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.

### 4.2 Tests performed with variation of influence quantities

#### 4.2.1 General

These tests are intended to determine the effects of variation in influence quantities. The range of variation of each influence quantity and acceptable limits of consequent variation in the indication of an assembly are given in Table 2. The range of variation of influence quantities indicated in Table 2 defines a nominal operating range within which the limits of the variation in indication stated by the manufacturer shall remain. These limits shall in no case exceed those laid down in Table 2.

In order to test the effect of variation in any one of the influence quantities listed in Table 2, all other influence quantities are normally maintained within the limits for standard test conditions given in Table 1, unless otherwise specified in the test procedure concerned.

#### 4.2.2 Tests for influence quantities of type F

These tests may be performed at any value of the quantity to be measured above or equal to 10 $\dot{H}_0$ or 10 $H_0$. From the result of each test, the respective variation of the relative response $r$ can be determined.

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2 International Bureau of Weights and Measures: The International System of Units, 8th edition, 2006.

It is acceptable that some effects of the influence quantities classified as type F could be regarded as effects produced by type S influence quantities. If these effects are small they shall be ignored in relation to the use of this standard. If during testing larger effects of type S are observed then the respective test shall be performed at a dose value of 10 $\dot{H}_0$ or 10 $H_0$ and these findings shall be reported in the type test report.

#### 4.2.3 Tests for influence quantities of type S

These tests shall be performed at a value of the quantity to be measured of less than or equal to 10 times the lower limit $\dot{H}_0$ or $H_0$ of the effective range of measurement, even zero dose (rate) is possible if no other specification is given in the respective subclause and a negative deviation can be excluded. The result of each test is a deviation $D$.

It is acceptable that some small part of the effects of the type S influence 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 standard. If larger effects of Type F or significant negative effects are observed during testing, then the respective test shall be performed at a dose value of 10 $\dot{H}_0$ or 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 for influence quantities of type F the necessary number of measurements may be increased.

### 4.3 Consideration of non-linearity

The effect of a non-linear response shall be regarded.

Testing should be undertaken in a dose (rate) region where non-linearity is not significant. A practical method is to first undertake a linearity test in order to identify the region of non-linearity, and then perform the other tests in a dose (rate) region where non-linearity is negligible (1 % to 2 %).

### 4.4 Consideration of several detectors or signals in a dose (rate) meter

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

### 4.5 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 indicated value may be estimated with sufficient precision to demonstrate compliance with the test in question. The recommendations of ISO 11929 should be employed.

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

### 4.6 Radiation sources

The reference neutron radiation source shall be as described in ISO 8529-1 and can be one of the following: $^{241}$Am-Be radionuclide source, $^{252}$Cf spontaneous fission source, $^{252}$Cf source moderated by $D_2O$ sphere of 30 cm in diameter or by well defined moderator/filter or accelerator target sources (ISO 8529). For thermal and epithermal neutron reference fields, accelerator target, reactor beams, $^{241}$Am-Be or $^{252}$Cf sources with well defined moderator/filter arrangements may be used.

The nature, construction and conditions of use of the source shall be in accordance with recommendations of ISO 8529-1, ISO 8529-2, and ISO 8529-3.

The quantity value of the ambient dose equivalent rate from these sources may be obtained from the spectral fluence rate distribution delivered by the source and the fluence-to-ambient dose equivalent conversion coefficients (see Annex A, Table A.1). Average fluence-to-ambient dose equivalent conversion coefficients for five reference sources are given in Annex A, Table A.2. The neutron fluence-to-ambient dose equivalent conversion coefficients employed shall be specified by the manufacturer (see 13.2 e).).

The ambient dose equivalent rate of the photon emission from the source should be significantly less than that due to neutrons, or suitable shielding be used to ensure that this is true at the detector. The response of the device to gamma rays shall be determined with $^{137}$Cs or $^{60}$Co source and/or with other photon sources if necessary.

### 4.7 Work place neutron fields

Work place neutron fields may be:

a) simulated fields specified in ISO 12789 or

b) other work place environments whose fields are well defined by spectral calculations and/or measurements traceable to or recognized by a primary standards laboratory.

The nature, production and conditions of use of the fields shall be in accordance with the recommendations of ISO 12789.

The conventional true ambient dose equivalent rate at the point of measurement in these fields may be obtained from the spectral fluence rate distribution and the fluence-to-ambient dose equivalent conversion coefficients (see Annex A, Table A.1).

NOTE Survey fields may differ considerably from the reference radiation fields. In order to increase the accuracy of the measurement in such fields, correction factors may be applied to the reading of the instrument; these are calculated from the fluence response of the device, the fluence-to-ambient dose equivalent conversion coefficients, and the spectral fluence of the calibration and the survey field, respectively.

## 5 General requirements

### 5.1 Summary of requirements

In Tables 2, 4, 5, and 6 instrument requirements are summarized.

### 5.2 General characteristics

#### 5.2.1 Effective range of measurement

The effective range of measurement, starting at $\dot{H}_0$ or $H_0$ shall not be less than the following:

a) for dose equivalent (rate) meters with an analogue type of display (e.g. linear or logarithmic), one range per order of magnitude from 10 % to 100 % of the scale maximum angular deflection on each scale range, and for dose equivalent (rate) meters with two ranges per order of magnitude from 30 % to 100 % of the scale maximum angular deflection on each scale range;

b) for dose equivalent (rate) meters with a digital display, from an indication in the second least significant digit up to the maximum indication on each range. As an example, for a display with a maximum indication of 9 999,9, the effective range can extend from 1,0 to 9 999,9 – i.e. four orders of magnitude – or from 3,0 to 9 999,9 – i.e. three and a half orders of magnitude;

c) for dose equivalent (rate) meters with a digital and scientific display (e.g. x,yz E ± ab) the mantissa shall have three digits at least (for instance 1,00 to 9,99). The manufacturer

shall define the effective range of measurement (for instance $1{,}00 \cdot 10^{-7}$ to $9{,}99 \cdot 10^{-2}$ with the unit $Sv \cdot h^{-1}$).

For dose equivalent (rate) meters with more than one scale, the effective range of measurement shall be from 10 % of the lowest scale range to 100 % of the highest scale and all scales shall be arranged to make the total range covered by the effective range of measurement.

When the test methods do not extend over the entire effective range of measurement and any of the observed variations are near the permitted limit, further tests to demonstrate compliance with the requirement in question over the whole effective range of measurement may be necessary. Agreement on supplementary tests shall be reached between the purchaser and the manufacturer.

#### 5.2.2 Minimum range of measurement

The minimum effective range of measurement of dose equivalent rate shall cover at least four orders of magnitude and shall include 10 $\mu Sv \cdot h^{-1}$ for the measuring quantity $\dot{H}^*(10)$.

The minimum effective range of dose equivalent shall cover at least four orders of magnitude and shall include 0,1 mSv.

#### 5.2.3 Rated range of an influence quantity

The rated range of any influence quantity has to be stated in the documentation. In addition, some rated ranges have to be stated on the instrument, see 5.3.2.

#### 5.2.4 Minimum rated range of influence quantity

The minimum rated range of the specified influence quantity is given in the second column of Tables 2, 4, 5 and 6.

#### 5.2.5 Indication of the assembly

The indication of the assembly shall be in units of ambient dose equivalent (rate), for example in millisieverts (per hour). The indication may be on an analogue type of display or on a digital display. It is recommended that the indication may be read remotely.

### 5.3 Mechanical characteristics

#### 5.3.1 IP classification

The IP classification shall be stated by the manufacturer according to IEC 60529. The minimum IP requirement for hand-held instruments is given in IEC 62706.

#### 5.3.2 Assembly labels and markings

An assembly for the measurement of neutron ambient dose equivalent (rate) shall be labelled with a specific indication of its intended use.

The following information shall be clearly visible on the dose (rate) meter:

a) the quantity that is measured;
b) the effective range of measurement;
c) the type of radiation (for example neutron) the dose (rate) meter is suitable for;
d) the rated range of particle energy;
e) reference point and reference direction (or in the manual);
f) serial number of the instrument.

#### 5.3.3 Ease of decontamination

The assembly shall be constructed in such a manner as to facilitate decontamination. In order to achieve this, it should, for example, have a smooth non-porous external surface, which is free from crevices, or be usable when placed inside a thin and flexible envelope, provided with transparent parts to allow the instrument scale to be read.

### 5.4 Interface requirements

The provision of an output connection for a remote readout, which shall be appropriately marked, is recommended (for example for an external counter or integrator, a recorder or a secondary digital display).

If the assembly is equipped with a data processor and memory, an output to an external data device is recommended, for example by a serial data interface.

### 5.5 Algorithm to evaluate the indicated value

For the type test of multiple detector assemblies according to this standard, the manufacturer shall deliver the evaluation algorithm of the indicated value starting from the signal(s) of the detector(s) and ending at the indicated value. This shall include all the calculations and/or the decision tree.

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

## 6 Radiation detection requirements

### 6.1 General

All influence quantities dealt with in this clause are regarded as of type F.

NOTE 1 The requirements for the influence quantity *radiation energy and angle of radiation incidence* are given with respect to the reference response $R_r$ 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 1). The possible reference radiations can be found for neutron radiation in Table 1 of ISO 8529-1:2001. The most used reference radiations are given in Table 1, but it may 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 details regarding the reasons for the non-symmetric limits for the relative response due to radiation energy and angle of radiation incidence see IEC TR 62461.

### 6.2 Consideration of the uncertainty of the conventional quantity value

The expanded (k = 2) relative uncertainty, $U_{rel}$, of the conventional quantity value of the dose equivalent or dose equivalent rate shall be taken into account and should be less than ±20 %. This is accounted for by adding $U_{rel}$ to the allowed variation of the relative response. 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 equivalent (rate) shall be considered. In case of other requirements, the consideration is mentioned in the respective method of test.

### 6.3 Constancy of the dose rate response, dose dependence and statistical fluctuations

#### 6.3.1 General

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

If the manufacturer can show that the technical design of the dose (rate) meter ensures the fulfilment of the requirements on constancy of the dose rate response for a large range of dose rate values, then the number of tests can be reduced.

### 6.3.2 Requirements

a) 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 rate response shall not exceed –17 % to +25 % over the whole of the effective range of measurement for neutron reference radiations chosen. The dose shall be varied over the whole range of dose specified by the manufacturer for dose rate measurements.

b) The statistical fluctuations of the indication measured as coefficient of variation shall fulfil the requirements given in Table 3.

### 6.3.3 Test method using sources

a) Source to be used

For the purpose of this test, the conventional quantity value of the ambient dose equivalent (rate) at the point of test shall be known. The tests shall be performed with reference sources of appropriate activity irradiating the dose (rate) meter free in air as given in Table 1, e.g. $^{241}$Am-Be for neutron radiation.

b) Tests to be performed

The response shall be measured for at least three dose rate values in each order of magnitude of the effective range of measurement of dose rates. These shall be at approximately 20 %, 40 % and 80 % of each full order of magnitude. At different dose rate values, different dose values in the rated range shall be applied as well. In total, $n$ repeated measurements at each of the $w$ dose rate values shall be performed, depending on the effective range of measurement of dose rate. From these measurements of the $w$ response values, the variation of the relative response due to the non-constancy of the response may be determined.

### 6.3.4 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 rate 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 from –17 % to +25 %. Also, using the $w$ values of the coefficients of variation and the values of $c_1$ and $c_2$ given in Table 3, show that

- for ($w$ – 2) dose rate values the coefficients of variation are less than $c_1$ times the limits given in Table 3 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.

In that case, the requirements a) and b) of 6.3.2 can be considered 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 More information on the test procedure is given in [8].

### 6.3.5 Test procedure with variation of the calibration distance

Several practical procedures are established in ISO 8529-2 to determine the instrument response by employing the reference neutron radiation sources, taking into account the characteristic contribution of scattered radiation and the position of the reference point of the device. The procedures include the determination of indicated values at a series of calibration

distances, where the indicated values may range over one or more orders of magnitude. Response, scatter contribution and geometry parameters are determined by data analytical fitting methods. In this case, any indicated value may count as a point in the respective scale ranges given in 6.4.2. For the determination of the relative error in the respective scale range, the fitted indicated values may be employed, if the fitted values for the scatter and geometry parameters are in agreement with calculated and/or experimentally determined experience values.

### 6.3.6 Equivalent electrical test method

In the event that the full range of ambient dose equivalent rates required for the above tests cannot be provided by the sources of neutron radiation available, it is permissible to employ an equivalent electrical test in order to determine the relative error at the ambient dose equivalent rates that cannot be provided by the sources of radiation.

In this case, the radiation sources shall be capable of providing at least one ambient dose equivalent rate in the upper part of the effective range of measurement of the assembly for the type test, and at least one ambient dose equivalent rate in the lower part of the effective range of measurement of the assembly. The electrical signal shall have a form which simulates as closely as necessary the form of signal delivered by the detector and shall be injected at a point that will test the entire assembly apart from the detector itself or the photomultiplier in the case of a scintillator detector.

If $\dot{H}^{*}_{i1}(10)$ is the indicated ambient dose equivalent rate when the assembly is subjected to a conventionally true ambient dose equivalent rate, $\dot{H}^{*}_{t}(10)$, from the neutron reference source available, then an electrical signal, $S_1$, shall be injected such as to produce the same indicated value, $\dot{H}^{*}_{i1}(10)$. Then if another indicated value $\dot{H}^{*}_{i2}(10)$ is produced by an input signal, $S_2$, the relative error is given by:

$$U = \left( \frac{\dot{H}^{*}_{i2}(10) \times S_1}{\dot{H}^{*}_{i1}(10) \times S_2} - 1 \right)$$

and the observation shall be within the limits given in 6.3.7. If the electrical test method is used, this should be stated in the accompanying documents.

### 6.3.7 Interpretation of the equivalent electrical test results

It is necessary to make allowance for the relative uncertainty U(k = 2) in the values of the conventional true ambient dose equivalent rates employed in the test. If no single observed mean value of the relative error, U, exceeds ±(20 % + U), then the requirement for constancy of the dose rate response can be considered met.

## 6.4 Variation of the response due to neutron energy

### 6.4.1 General

The response of all neutron dose (rate) meters is very dependent on the neutron energy [1]. For radiological protection purposes, it would be desirable for the variation of the response with the neutron energy over the entire energy range from thermal to the maximum energy specified by the manufacturer not to exceed a factor of 1,5. However, at the time of publication, such requirement is not practically achievable.

As all existing devices and those being developed are essentially based on appropriate detector response calculations, the results of these calculations shall be made available for the entire neutron energy range with calculated data at least at two energy points per decade of neutron energy.

### 6.4.2 Requirements

The relative ambient dose (rate) equivalent response, $r_{H^*(10)}$ and 〚C〛 $r_{\dot{H}^*(10)}$ 〚C〛 due to variation of the neutron energy shall be for

| | |
|---|---|
| thermal – 50 keV energy range | the manufacturer shall specify the variation of the ambient dose (rate) equivalent relative response with the neutron energy. The relative response shall be 〚C〛 *Text deleted* 〚C〛 within the range from 0,2 to 8,0. |
| 50 keV – 10 MeV energy range | within the range from 0,5 to 2,0. |
| 10 MeV – 20 MeV | the manufacturer shall specify the variation of the ambient dose (rate) equivalent relative response with the neutron energy. The variation of the relative response shall be 〚C〛 *Text deleted* 〚C〛 within the range from 0,2 to 2,0. |

The relative response herein is relative to the reference neutron energy and 0° between the incident neutron radiation and the reference direction. The instrument axis, the reference plane and reference direction of incidence shall be defined by the manufacturer.

The requirement for the neutron energy range from 50 keV to 10 MeV is mandatory for every instrument. For the remaining energy range the manufacturer shall state the energy range where the stated requirements are met by their instrument.

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.

### 6.4.3 Test method

For this test, the dose (rate) meter shall be placed free in air. 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.

Since it is impracticable to investigate the performance of an assembly and to validate the calculated data over nine decades of neutron energy from thermal neutrons up to 20 MeV, the following energies may be used:

a) at least two neutron energies below 50 keV, one of them being thermal neutron energy;

b) at least three neutron energies in the energy range between 50 keV and 10 MeV 〚C〛 (one of them 144 keV) 〚C〛;

c) at least 〚C〛 two broad sources ($D^2O$-moderated $^{252}Cf$ and e.g. $^{252}Cf$ or $^{241}Am$-Be) 〚C〛;

d) at least one neutron energy exceeding 10 MeV.

Only tests at energies that are within the manufacturer's specified energy range are required. In addition, it is recommended to state the response to standardized simulated work place neutron field sources.

〚C〛 The test distance should be at least 3 times the sum of the largest linear dimension of the source and the detector. In case of neutron fields according to ISO 8529, the scatter contribution to the indicated value shall be determined in compliance with ISO 8529-2 and the indicated value shall be corrected for scattered neutrons. 〚C〛

In principle, this test is best performed at the same ambient dose equivalent rate for each neutron energy. In practice, this may not be possible, in which case the indicated ambient dose equivalent rate of each neutron energy shall be corrected for the relative response (interpolated if necessary) at the same indication as for the reference neutron radiation.

Using the provided computational response function calculate the ambient neutron dose equivalent (rate) at the selected neutron energies in 6.4.3 a) through d) and compare them with the experimentally determined values.

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

#### 6.4.4 Interpretation of the results

When all experimentally measured relative response values due to variation of the neutron energy are within the ranges specified in 6.4.2 and the calculated values of the ambient dose equivalent (rate) are within ± 20 % of the experimentally measured values, then the requirements of 6.4 are considered met.

### 6.5 Monte Carlo calculation of the instrument response

#### 6.5.1 General

The response of the existing and those being developed neutron dose (rate) meters in the neutron energy regions where measurements are not available or feasible is essentially based on Monte Carlo calculations. The calculated relative response curve is usually relative to $^{252}$Cf response.

#### 6.5.2 Requirements

A Monte Carlo response curve shall be provided by the manufacturer to cover the energy range stated by the manufacturer. Calculated numerical values of the response shall be provided to accompany each measured energy in 6.4.3 a) through d). Additionally calculated numerical values of the response shall be provided at additional energies to fill in the gaps between the available monoenergetic fields and to extend the data to cover the full energy range. Calculated numerical values of the response shall be provided at least in each order of magnitude of the neutron energy (e.g. $10^{-2}$ eV, $10^{-1}$ eV, $10^{0}$ eV, $10^{1}$eV,...,$10^{6}$ eV, $10^{7}$ eV, $>10^{7}$ eV). The accuracy of the Monte Carlo results for the detector response shall be such that the calculated ambient neutron dose equivalent (rate) at the selected neutron energies in 6.4.3 a) through d) is within ±20 % of the measured ambient neutron dose equivalent (rate). Monte Carlo calculations shall be fully documented so that they can be repeated (or verified) by independent entity or laboratory.

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

#### 6.5.3 Test method

Verify that the Monte Carlo calculated response curve cover the entire energy region stated by the manufacturer. Verify that Monte Carlo calculations are fully documented and can be independently repeated. This can be accomplished either by repeating portion of the calculations or by reviewing the documentation. Verify that calculated numerical response values at the selected energies in 6.4.3 a) through d) are provided. Verify that calculated numerical response values at energies between those selected in 6.4.3 a) through d) are provided at least in each order of magnitude of the neutron energy.

#### 6.5.4 Interpretation of the results

The instrument meets the requirements in 6.5.2 if

a) Monte Carlo calculated response curve is provided that covers the entire energy region stated by the manufacturer, and

b) Monte Carlo calculations are fully documented and can be independently repeated, and

c) calculated and experimental data at the selected energy points in 6.4.3 a) through d) are within ±20 %, and

d) calculated numerical response values in each order of magnitude of the neutron energy between those energies selected in 6.4.3 a) through d) are provided.

### 6.6 Variation of the response due to angle of incidence

#### 6.6.1 General

This standard relates to detector assemblies with a wide angle of acceptance and having essentially circular symmetry in one plane. The standard recognizes the practical limitations of achieving a uniform response over 4π solid angle.

#### 6.6.2 Requirements

The variation of the indication of the assembly to radiation incident at any angle from 0° to 90° to the reference (calibration) direction in the reference plane shall not exceed ±25 % in the rated energy range.

The variation of the indication of the assembly to radiation incident at any angle from +90° to +180° and –90° to –180° to the reference direction in the reference plane shall be stated by the manufacturer. The variation of the indication of the assembly to radiation incident at any angle to the reference direction in a plane orthogonal to the reference direction should be stated by the manufacturer. The reference plane and the reference direction of incidence shall be defined by the manufacturer.

#### 6.6.3 Test method

The detection assembly shall be exposed to one of the reference neutron radiation sources specified in 4.6. The assembly shall be placed in its reference plane with the radiation source in the reference direction (i.e. the calibration direction defined by the manufacturer in relation to the radiation source being used). The calibration distance should be at least 3 times the sum of the largest linear dimension of the source and the detector. [C] In case of neutron fields according to ISO 8529, the scatter contribution to the indicated value shall be determined in compliance with ISO 8529-2 and the indicated value shall be corrected for scattered neutrons. [C] The detection assembly shall then be turned in the reference plane through angles from 0° to ±180° from this position in steps of 30° and the indicated values noted. Similar observations shall then be taken as the assembly is rotated in a plane orthogonal (perpendicular) to the reference direction.

#### 6.6.4 Interpretation of the results

The instrument meets the requirements of 6.6.2 if

a) the variation of the indication of the assembly to radiation incident at any angle from 0° to 90° to the reference direction in the reference plane does not exceed ±25 % and

b) the variation of the indication of the assembly to radiation incident at any angle from +90° to +180° and –90° to –180° to the reference direction in the reference plane does not exceed the values stated by the manufacturer and if provided

c) the variation of the indication of the assembly to radiation incident at any angle to the reference direction in a plane orthogonal to the reference direction does not exceed the values stated by the manufacturer.

### 6.7 Overload characteristics

#### 6.7.1 Dose equivalent meters

##### 6.7.1.1 Requirements

a) The dose equivalent meter shall read off-scale on the high side or shall indicate overload when exposed to doses greater than the maximum of its measuring range. This requirement shall apply to all ranges.

b) When subjected to dose rates high enough to cause wrong dose indication, there shall be indication that the equipment is not able to provide correct dose indication.

#### 6.7.1.2 Test method

The test may be carried out either with a suitable neutron source or by injection of a suitable signal into the input of the measuring assembly (see 6.3.6) if high neutron dose rates are not available.

a) Subject the dose equivalent meter to a dose between 1 Sv and 50 Sv and in excess of 10 times the maximum dose that can be indicated. The dose rate during the exposure shall be less than the maximum dose rate capability as specified by the manufacturer. The equipment shall not be reset or switched off for at least 30 min after the equipment has been subjected to the test dose.

b) Subject the dose equivalent meter to a dose rate 10 % in excess of that specified as the dose rate limit by the manufacturer for a period of 100 s. In case no error of the dose value (due to dose rate overload) is indicated, subject the dose equivalent meter to further increased dose rates in steps of 10 % for 100 s until the error indication of the dose value (due to dose rate overload) is displayed.

#### 6.7.1.3 Interpretation of the results

a) The indication shall be off-scale on the high side or overload shall be indicated and shall remain so until the dose indication is reset or the equipment is switched off.

b) Ensure that either the dose indication has increased appropriately (within the manufacturer's stated tolerance) or indication is given that the reading of dose (due to dose rate overload) is in error. Prior to the error indication the dose indication shall increase as appropriate within its tolerance.

### 6.7.2 Dose rate equivalent meters

#### 6.7.2.1 Requirements

The dose rate equivalent meter shall read off-scale on the high side or shall indicate overload when exposed to dose rates greater than the maximum of its measuring range. This requirement shall apply to all ranges.

#### 6.7.2.2 Test method

The test may be carried out either with a suitable neutron source or by injection of a suitable signal into the input of the measuring assembly (see 6.3.6) if high neutron dose rates are not available.

The dose rate equivalent meter shall be submitted for a period of 5 min to a dose equivalent rate 10 times the range (scale) maximum.

#### 6.7.2.3 Interpretation of the results

The indication of the dose equivalent rate shall read off-scale on the high side or indicate overload throughout this period. The dose rate equivalent meter shall function within the specification 5 min after completion of this test. If the device is not functioning within the specification, a warning shall be displayed. The warning may extinguish only when the device meets again the specifications without restrictions. This test is applicable to each range.

## 6.8 Response time

### 6.8.1 Requirements

The response time shall be such that, if there is a sudden change in the ambient dose equivalent rate, the indication shall reach the following value:

$$\dot{H}_{\mathrm{i}}^{*}(10)+\frac{90}{100}\left(\dot{H}_{\mathrm{f}}^{*}(10)-\dot{H}_{\mathrm{i}}^{*}(10)\right)$$

Where $\dot{H}_{i}^{*}(10)$ is the initial indicated value and $\dot{H}_{f}^{*}(10)$ the final indicated value, in a time smaller than those specified below:

a) 30 s for the increases or decreases of the ambient dose equivalent rate less than 0,1 mSv·h$^{-1}$;
b) 10 s for the increases or decreases of the ambient dose equivalent rate between 0,1 mSv·h$^{-1}$and 1 mSv·h$^{-1}$;
c) 4 s for the increases or decreases of the ambient dose equivalent rate greater than 1 mSv·h$^{-1}$.

The manufacturer shall state the response time.

### 6.8.2 Test method

The test may be carried out either with a suitable neutron source or by the injection of a suitable electrical signal into the input of the measuring assembly.

The initial and final ambient dose equivalent rates shall differ by a factor of at least 10 and measurements shall be carried out for both an increase and a decrease in the ambient dose equivalent rate by this factor.

If the electrical test method is employed, the injected signals shall correspond to the above requirements.

For the increasing ambient dose equivalent rate test, the detection assembly shall be subjected first to the higher ambient dose equivalent rate and the indicated value $\dot{H}_{f}^{*}(10)$ shall be noted.

The assembly shall then be subjected to the lower ambient dose equivalent rate for a time sufficient for the indication $\dot{H}_{i}^{*}(10)$ to reach a steady value and this indicated value shall be noted.

The ambient dose equivalent rate shall then be changed as quickly as possible to that corresponding to the indicated value $\dot{H}_{f}^{*}(10)$, and the time taken to reach the value given by the formula in 6.8.1 shall be measured.

The test for decreasing ambient dose equivalent rate shall be performed in the same way with the values of ambient dose equivalent rates corresponding to $\dot{H}_{f}^{*}(10)$ and $\dot{H}_{i}^{*}(10)$ interchanged.

### 6.8.3 Interpretation of the results

The instrument meets the requirements if the indication following a sudden change of the ambient equivalent dose rate reaches the value defined by the formula in 6.8.1 in time less than those specified in 6.8.1.

## 6.9 Relationship between response time and statistical fluctuations

The response time and the coefficient of variation of the statistical fluctuations are interdependent characteristics, for which acceptable limits are given above in 6.8.1 and 6.3.2.

For high ambient dose equivalent rates, it is recommended that, whenever possible, while conforming to the limits laid down for the statistical fluctuations, the response time should be reduced.

There is little advantage in reducing response time much below 1 s; in such cases, it would be more advisable to reduce the statistical fluctuations.

### 6.10 Dose equivalent rate alarm

#### 6.10.1 Requirements

Under standard test conditions, when the dose equivalent (rate) meter is subjected to a dose equivalent rate of 0,8 of the dose equivalent rate corresponding to the dose equivalent rate alarm set point for 10 min, the alarm shall not be activated for more than 10 % of the period of test. Similarly, at a dose equivalent rate of 1,2 times the alarm level set, the alarm shall be activated for at least 90 % of the test period. When the dose equivalent (rate) meter is subjected to dose equivalent rates of 1,2 times the dose equivalent rate alarm set point, the alarm shall actuate within 5 s or within a time such that the product of this time and the dose equivalent rate of the alarm point is less than 10 μSv.

When a dose equivalent (rate) meter utilises more than one radiation detector to cover the full range of dose equivalent (rates) indicated by the dose equivalent (rate) meter, these requirements apply to the relevant ranges for each detector separately.

#### 6.10.2 Test method

At least two tests shall be carried out, one with the alarm set near the maximum effective indicated value and one near the maximum of the second least significant decade.

#### 6.10.3 Interpretation of the results

The instrument meets the dose equivalent rate alarm requirement if it satisfies 6.11.1 requirement for 2 alarm set points, one near the maximum effective indicated values and one near the maximum of the second least significant decade. Allowance shall be made for the relative uncertainty (k = 2) in the conventional true dose equivalent rate to which the neutron dose (rate) meter is subjected. Where this is U, the dose rates used shall be: 0,8(1 – U) and 1,2(1 + U) of the dose equivalent alarm rate set point.

### 6.11 Dose equivalent alarm

#### 6.11.1 Requirements

Under standard test conditions, when the dose equivalent meter is subjected to a dose equivalent of 0,8 times the dose equivalent corresponding to the dose equivalent alarm set, no alarm shall be given, and when the dose equivalent meter is subject to a dose equivalent rate of 1,2 times the dose equivalent alarm set point, the alarm shall be actuated.

#### 6.11.2 Test method

At least two tests shall be carried out, one with the alarm set near the maximum effective indicated value and one with the alarm set near the maximum of the second least significant decade. The alarm shall be reset and then the dose equivalent meter shall be subjected to a conventionally true dose equivalent rate such that the alarm will not occur for at least 100 s. The time of exposure of the dose equivalent meter shall be measured.

#### 6.11.3 Interpretation of the results

The instrument meets the dose equivalent alarm requirement if it satisfies 6.12.1 requirement for 2 alarm set points, one near the maximum effective indicated value and one near the maximum of the second least significant decade and if the quotient of the alarm set point by the product of the dose equivalent rate used and the measured time lie within the range 0,8(1 – U) to 1,2(1 + U), where U is the relative uncertainty (k = 2) in the conventionally true dose equivalent rate.

### 6.12 Response to photon radiation

#### 6.12.1 Requirements

Practically all neutron radiation fields are contaminated by photon radiation, which leads to the necessity to determine the response to photon radiation.

The response to photon radiation shall be quoted in terms of the indication of the assembly per unit of photon ambient dose equivalent rate at the point of test.

Photon radiation incident on a neutron assembly may not only cause the assembly to give an indication, but it may also modify the response of the assembly to neutron radiation. Therefore, there are two separate requirements.

a) The indication produced by a $^{137}$Cs or $^{60}$Co photon ambient dose equivalent rate of 10 mSv·h$^{-1}$ shall not be greater than the indicated value due to a neutron ambient dose equivalent rate of 0,1 mSv·h$^{-1}$.

b) In a neutron reference field producing an indication of 1 mSv·h$^{-1}$, exposure to 10 mSv·h$^{-1}$ from $^{137}$Cs or $^{60}$Co photon radiation shall not change this neutron indication by more than 10 %. The $^{137}$Cs or $^{60}$Co sources used for the above tests should conform to the requirements of the ISO 4037 series.

c) Furthermore, since in some situations where neutron ambient dose equivalent rate is to be measured, high-energy photon radiation (for example 6 MeV from $^{16}$N) may be present, the response to photon radiation shall, by agreement between the manufacturer and the purchaser, be checked at higher energies as well as with $^{137}$Cs or $^{60}$Co energy. In this case, the manufacturer shall state the response to high-energy photon radiation.

#### 6.12.2 Test method

For requirement a) of 6.13.1, the assembly shall be exposed to a $^{137}$Cs or $^{60}$Co source in a field having an ambient dose equivalent rate of 10 mSv·h$^{-1}$ at the reference point of the assembly.

For requirement b) of 6.13.1 the assembly shall be exposed to the neutron reference source so that an indicated value of 1 mSv·h$^{-1}$ is obtained. The assembly is now additionally exposed to a $^{137}$Cs or $^{60}$Co source such that the photon dose equivalent rate at the point of test is 10 mSv·h$^{-1}$.

For requirement c) of 6.13.1, the radiation sources used for this test shall conform to the ISO 4037 series.

#### 6.12.3 Interpretation of the results

The requirements stated in 6.13.1 a) and c) are satisfied if the indication produced by a $^{137}$Cs and higher energy (> 1,5 MeV) photon ambient dose equivalent rate of 10 mSv·h$^{-1}$ is less than the indicated value due to a neutron ambient dose equivalent rate of 0,1 mSv·h$^{-1}$. The response to photon radiation shall be quoted in terms of the indication of the assembly per unit of photon ambient dose equivalent rate at the point of test.

The requirement in 6.13.1 b) is met if the indication of the neutron ambient dose equivalent rate does not change by more than 10 % when exposed to photon dose equivalent rate of 10 mSv·h$^{-1}$ from a $^{137}$Cs source.

### 6.13 Response to other external ionizing radiations

〈C〉 If the detector's cover does not shield alpha and beta radiation, the response due to alpha and beta radiation should be measured – and the results should be documented. 〈C〉

# 7 Additivity of indicated value

## 7.1 Requirements

The indicated value shall be additive with respect to simultaneous irradiation with different types of radiation (for example, photon and neutron) and with different neutron energies and angles of radiation incidence.

If the dose (rate) meter uses only one signal (measured with one detector) to evaluate the indicated value, then this requirement is fulfilled.

If a dose (rate) meter uses more than one signal (measured either with several detectors or with one detector using for example pulse height analysis) to evaluate the indicated value, then this requirement is not automatically fulfilled. In that case, it shall be ensured that the relative change in indication, $\Delta g_{\mathrm{mix}}$ caused by the mix of radiation shall not exceed $\pm 0{,}1$.

If the algorithm used to evaluate the indicated value, (see 5.5) is either a linear combination of the signals or a linear optimization of them, then this requirement is fulfilled or no tests are required.

## 7.2 Test method

Perform subsequently two irradiations under the two different irradiation conditions K and L (different energies, different angles of incidence or even different types of radiations) with the conventional quantity values $H_{\mathrm{tK}}$ and $H_{\mathrm{tL}}$. Determine the indicated values $H_{\mathrm{iK}}$ and $H_{\mathrm{iL}}$ for the two irradiations. Then perform a third simultaneous irradiation under the two irradiation conditions K and L with the conventional quantity value $H_{\mathrm{t(K+L)}} = H_{\mathrm{tK}} + H_{\mathrm{tL}}$ and determine the indicated value $H_{\mathrm{i\,(K+L)}}$ or this simultaneously mixed irradiation.

The relative change in indication is then given by:

$$\text{〚C〛}\ \Delta H_{\mathrm{imix}} = \frac{H_{\mathrm{iK}} + H_{\mathrm{iL}} - H_{\mathrm{i(K+L)}}}{H_{\mathrm{i(K+L)}}}\ \text{〚C〛}$$

$\Delta H_{\mathrm{imix}}$ shall be determined for any value of $H_{\mathrm{tK}}$ and $H_{\mathrm{tL}}$ and any simultaneous combination of radiation fields $S_{\mathrm{K}}$and $S_{\mathrm{L}}$. As simultaneous irradiations are very difficult to perform, the use of calculations as a replacement for the simultaneous irradiations is permitted and recommended for this test. A prerequisite of the use of calculations is the knowledge of measured response values of each signal to all the irradiation conditions K and L and of the evaluation procedure to determine the indicated value from these signals. The calculation of the response of the entire dose (rate) meter with the aid of radiation transport simulations to determine the response values of each signal to all the irradiation conditions is not permitted.

The non-linearity of the signals is treated in 4.3 and 6.3. Therefore, when no calculation is performed, the signals shall be corrected for non-linearity for this test. When different dose (rate) meters are used to determine $H_{\mathrm{iK}}$, $H_{\mathrm{iL}}$ and $H_{\mathrm{i\,(K+L)}}$, any difference in the reference calibration factor shall be corrected.

## 7.3 Interpretation of the results

The relative change in indication, $\Delta H_{\mathrm{imix}}$ shall not exceed $\pm 0{,}1$. In this case, the requirements of 7.1 can be considered met.

# 8 Software

## 8.1 General

The final version of the software shall be available at the beginning of the type test, as a great part of the software test is indirectly covered by the metrological test. The manufacturer shall be aware of the fact that any change of the “data relevant part” of the software may question the validity of the type test.

NOTE In modern instruments, the software has an increasing importance for the generation of the measured value. Therefore, the type test automatically includes the performance of the software running in the device under test. This is considered by the given requirements.

The requirements given are guided by the WELMEC software guide 7.2, see [7]. The requirements are based on the requirements for instruments with embedded software in a built-for-purpose measuring instruments (Type P) and a risk class B (low level).

## 8.2 Requirements

### 8.2.1 General requirements

The requirements set shall safeguard against any unintended modification of the data software. In addition, any attempted modification of the software shall be prohibited unless it is done under the supervision of authorized personnel and in the intended way.

### 8.2.2 Design and structure of the software

The software shall be designed in such a way that the part relevant to the indicated value is not affected by other software unless the effect is required for the correct use of the dose equivalent (rate) meter.

NOTE One possible technical solution is to separate the software into two parts. One part may contain all the functions necessary to evaluate, store and display the indicated values. This part is the “data relevant part”. The other parts of the software, the “non data relevant part”, may contain, for example, the value, the date and the time of a maximum of an indication. The data relevant part has well defined functions (software interface) that are used to communicate with the non data relevant software parts. This technical concept of software separation has the advantage, that the “non data relevant part” may be modified without influencing the “data relevant part”. The concept of software separation is state of the art in software engineering.

### 8.2.3 Protection of the software and data

#### 8.2.3.1 Identification

The “data relevant part” of the software (see note to 8.2.2) shall have an identification. It shall be possible to display this identification while the software is running. This identification can be compared with the identification given in the test record or in the user instructions.

NOTE If the identification automatically changes when the software is changed – in that case a simple version number is not sufficient – an additional benefit is given. Any change of a bit in the stored software of the dose equivalent (rate) meter, e.g. due to radiation, is recognized. One possible technical solution is a check sum algorithm (at least CRC-16) built over the software (see [7]). The reference value of the checksum of all bytes of the software is calculated and is stored. During startup of the instrument, the checksum is calculated again and compared with the stored reference value. In case a change occurred, the software stops and supplies an appropriate error message.

#### 8.2.3.2 Alarm under abnormal operating conditions

When abnormal operating conditions occur in components of the dose equivalent (rate) meter, this shall be indicated. These abnormal operating conditions include those that could lead to a faulty indication or loss of dose information, for example high voltage failure in a photomultiplier tube.

#### 8.2.3.3 Control of input data

All data used for the determination of the indicated value, for example, calibration factors and high voltage, shall be secured against unauthorized modification.

NOTE One possible technical solution is to require a password before any change of such data.

#### 8.2.3.4 User interfaces, hardware interfaces and software interfaces

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

NOTE In principle, it is possible to circumvent a software interface. This can usually be excluded by software separation, see note to 8.2.2, when the data relevant part of the software is realized in a separate binary file.

### 8.2.4 Documentation

#### 8.2.4.1 Documentation in the instruction manual

All functions, menus and submenus of the software shall be described in the instruction manual, see 13.1.

#### 8.2.4.2 Documentation for the type test

In addition to the documentation listed in Clause 13, the following information shall be given by the manufacturer for the purpose of type testing:

– a description of the structure of the software according to 8.2.2;
– the method to evaluate and display the identification, and to prevent measurements conducted with changed software, see 8.2.3.1;
– the measures to recognize abnormal operation conditions, see 8.2.3.2;
– a complete list of all relevant parameters, their ranges and nominal values, and the method to make sure that they are in allowed ranges, where they are stored, how they may be viewed, and how they can be changed, see 8.2.3.3;
– a complete list of all commands (e.g. menu items) and values that can be received via the interfaces, including their effect, see 8.2.3.4.

## 8.3 Test method

### 8.3.1 General

Testing of software can be very complex; however, it shall not dominate the testing-time. Therefore, no specific test is given and a large amount of responsibility is handed over to the manufacturer. The only test is done indirectly by performing the type test with the final version of the software and using the manufacturer's documentation, see 8.2.4, to perform the tests. The only test is on the documentation.

### 8.3.2 Testing the documentation

By using the software during the type test a lot of menus will be used. All of them shall be documented in the instruction manual. The rest of the menus shall be checked by "playing" with the running software and comparing the corresponding parts of the instruction manual. If the menus found in the software and those found in the instruction manual all fit together, the requirement is met. This should also be done for additional software and for the interfaces. In addition, the identification (see 8.2.3.1) shall be displayed and given in the certificate.

# 9 Electrical characteristics

## 9.1 Stability of zero indication with time

### 9.1.1 Requirements

The indication of a dose equivalent (rate) meter shall not vary by more than $\pm$ 0,2 $H_0$ or $\pm$ 0,2 $\dot{H}_0$ during the 300 min after it was switched on taking allowance for any change in $H_0$ due to the ambient background during this period.

### 9.1.2 Test method

Switch on the dose equivalent (rate) meter and leave it for a period of 30 min. If a zero-set control is available to the operator, this shall then be adjusted to bring the indication to a point stated by the manufacturer. For some dose equivalent (rate) meters with a non-linear scale, such a control is used to bring the indication to some reference point rather than to zero. If this is the case, the control shall be set to bring the indication to the appropriate reference point.

The dose equivalent (rate) meter shall be left in this condition and the reading noted every 30 min for a further 270 min period.

### 9.1.3 Interpretation of the results

If the noted readings are proved to be within the limits of 9.1.1, then the requirements are met.

## 9.2 Warm-up time

### 9.2.1 Requirements

The manufacturer shall state the warm-up time.

### 9.2.2 Test method

With the assembly switched off, expose it to appropriate reference source of radiation that will provide an indication of at least half of scale maximum on the most sensitive scale range or decade.

Switch on the assembly and wait for the manufacturer stated warm-up time. Then take 10 to 20 measurements of the dose equivalent (rate) and take the average value.

Thirty minutes after switching on the assembly, take another 10 to 20 measurements of the dose equivalent (rate) and use the average value of these measurements as the "final value" of the indication.

### 9.2.3 Interpretation of the results

If the final value and the average value taken immediately after the manufacturer stated warm-up time are within ±10 %, then the requirements of this test are met.

## 9.3 Power supplies – battery operation

### 9.3.1 General

Ways to check the battery condition under maximum load shall be provided. The indication of the remaining battery capacity, for which the performance of the assembly will remain within the requirements of this standard, shall be clearly indicated on the display.

Batteries may be connected in any desired manner but shall be individually replaceable; the polarity shall be clearly indicated on the assembly by the manufacturer.

#### 9.3.2 Requirements

The manufacturer shall state the makers (manufacturers) and types of batteries with which the requirements of this standard are fulfilled. Only primary or secondary batteries of physical dimensions as specified in IEC 60086-1 or IEC 60086-2 should be used.

The capacity of the batteries should be such that, after 40 h of intermittent use[3] under standard test conditions, the indication of the dose equivalent (rate) meter shall not differ more than ±10 % of its initial value, other functions remaining within specification.

For secondary batteries the manufacturer shall indicate the charging time.

Below –10 °C, the capacity of most types of batteries strongly decreases with decreasing temperature. This shall be considered.

#### 9.3.3 Test method

##### 9.3.3.1 General

The evaluation of the remaining battery capacity of the dose equivalent (rate) meter can be done either by measuring the actual voltage of the internal batteries or, especially for secondary batteries, by performing charge measurements during use and recharging.

Two test methods are provided. The first method uses batteries and shall be chosen if the remaining battery capacity is determined by performing charge measurements during use and recharging, the second method uses a power supply and may be chosen if the remaining battery capacity is determined by measuring the actual voltage of the internal batteries.

##### 9.3.3.2 Test using batteries

###### 9.3.3.2.1 General

New primary batteries or fully charged secondary batteries of the type indicated by the manufacturer shall be used for this test.

###### 9.3.3.2.2 Test method

Expose the neutron dose (rate) meter to a dose equivalent rate of between10 $\mu Sv \cdot h^{-1}$ and 1 $mSv \cdot h^{-1}$.

Leave the neutron dose (rate) meter working in this field for a period of 8 h followed by 16 h with the dose neutron dose (rate) meter switched off. Perform this test for 5 consecutive days and note the reading at the end of the period.

###### 9.3.3.2.3 Interpretation of the results

If the indication of the dose equivalent (rate) meter does not differ more than ±10 % of its initial value and no indication that the battery voltage is low, for example "low battery", then the requirements are met.

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[3] 40 h intermittent use means 8 h continuous use followed by 16 h with the dose equivalent (rate) meter switched off, for 5 consecutive days.

#### 9.3.3.3 Test using power supply

##### 9.3.3.3.1 General

The internal batteries shall be removed and the instrument connected to an external power supply with a suitable series resistor to simulate the battery impedance. The power supply shall be set to the nominal battery voltage $U_{\text{nom}}$.

##### 9.3.3.3.2 Test method

Expose the neutron dose (rate) meter to a dose equivalent rate of between 10 $\mu$Sv·h$^{-1}$and 1 mSv.h$^{-1}$. The instrument shall be switched on and allowed to stabilise.

The neutron dose (rate) meter indication $\dot{G}_{\text{nom}}$ shall then be recorded. The supply voltage shall then be reduced until the instrument indicates that the battery voltage is low, for example "low battery". The corresponding supply current $I_{\text{low}}$ shall be noted together with the instrument indication $\dot{G}_{\text{low}}$.

##### 9.3.3.3.3 Interpretation of the results

The test is passed if the following requirements are met:

– $0{,}9 \leq \dfrac{\dot{G}_{\text{low}}}{\dot{G}_{\text{nom}}} \leq 1{,}1$,

– all auxiliary functions operating as selected and

– $\dfrac{Q_{\text{nom}}}{I_{\text{low}}} \geq 40\ \text{h}$,

Where $Q_{\text{nom}}$ is the nominal capacity of the batteries (given e.g. in mA h) for the appropriate discharge conditions and considering the rated range of temperature (see 10.2).

### 9.4 Power supplies – Mains operations

#### 9.4.1 Requirements

Mains operated dose equivalent (rate) meters shall be designed to operate from single-phase 50 Hz (60 Hz in some countries) AC supply voltage in one of the following categories:

- Series I: 220 V to 230 V
- Series II: 100 V to 120 V and/or 240 V

(Nominal single-phase voltage in some countries is 117 V and/or 234 V, 60 Hz.)

Mains operated dose equivalent (rate) meters shall be capable of operating from mains supplies with a supply voltage tolerance of +10 % and –12 % of the nominal value, and a supply frequency of 50 Hz ± 3 Hz or 60 Hz ± 3 Hz.

The indication of dose equivalent (rate) shall remain within ±10 % over this range of supply voltage, other functions remaining within specification.

#### 9.4.2 Test method

Place the detection assembly in a field of neutron radiation at a point where the ambient dose equivalent rate corresponds to approximately three times the lower limit of the effective range of measurement. With the supply voltage at its nominal value $U_{\text{N}}$ take the mean of sufficient readings of ambient dose equivalent rate. Take the mean of sufficient readings with the

supply voltage 10 % above the nominal value and the mean of sufficient readings with the supply voltage 12 % below the nominal value.

Repeat the above tests at an ambient dose equivalent rate corresponding to at least two thirds of the upper limit of the effective range of measurement.

Expose the assembly to both ambient dose equivalent rates as above. At each rate, take the means of a sufficient number of indicated values with the supply frequency at its nominal value 50 Hz (or 60 Hz), at 53 Hz (or 63 Hz) and at 47 Hz (or 57 Hz).

If there is no timing function based on the mains frequency, then the test of frequency variation needs not be performed.

#### 9.4.3 Interpretation of the results

If the indication of the dose equivalent (rate) meter does not differ more than ±10 % of its initial value, then the requirements are met.

## 10 Environmental requirements

### 10.1 General

The influence quantities ambient temperature and temperature shock are considered to be of both types F and S, the influence quantities relative humidity and atmospheric pressure are considered to be of type F and the influence quantity storage and transport is considered to be of type S.

### 10.2 Ambient temperature

The instrument shall comply with IEC 62706 concerning ambient temperature for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before, during and after the test.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain from –15 % to +22 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source.

### 10.3 Temperature shock

The instrument shall comply with IEC 62706 concerning temperature shock for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before, during and after the test.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain from –15 % to +22 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source.

### 10.4 Relative humidity

The instrument shall comply with IEC 62706 concerning relative humidity for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before, during and after the test.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain from –15 % to +22 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source.

### 10.5 Atmospheric pressure

In general, atmospheric pressure will have an insignificant influence on the response of the assembly.

Representative tests at other atmospheric pressures need be performed only if required, for example if the assembly is being used in airborne measurements under low-pressure conditions.

### 10.6 Protection against moisture and dust (IP classification)

The instrument shall comply with IEC 62706 concerning IP classification for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before, during and after the test.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain within ±5 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source.

### 10.7 Storage and transport

All apparatus shall be designed to operate within the specifications of this standard after sufficient time has been allowed to reach ambient temperature following storage (or transport)at any temperature between –25 °C and +50 °C, without batteries, for a period of at least three months in the manufacturer's packaging.

In certain circumstances, more severe specifications may be required, such as capability for withstanding air transport at low ambient pressure.

## 11 Mechanical requirements

### 11.1 General

The influence quantities drop on a surface, vibration, microphonics and mechanical shock are considered to be of type S.

### 11.2 Drop test

The instrument shall comply with IEC 62706 concerning drop test for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before and after the test.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain within ±5 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source. After the test the instrument shall be inspected and it shall be working properly.

### 11.3 Vibration test

The instrument shall comply with IEC 62706 concerning vibrations for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before, between and after the tests.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain within ±5 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source. After the test the instrument shall be inspected and it shall be working properly.

### 11.4 Microphonics impact

The instrument shall comply with IEC 62706 concerning microphonics impact for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before and after each test.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain within ±5 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source. After the test the instrument shall be inspected and it shall be working properly.

### 11.5 Mechanical shock

The instrument shall comply with IEC 62706 concerning mechanical shock for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with a reference neutron source under standard test conditions. The measurements shall be conducted before, during and after the test.

The instrument indicated values of the dose equivalent and ambient dose equivalent rate shall remain within ±5 % of the values before the test under standard test conditions. No alarms or spurious indications shall be observed during the exposure to the influence quantity without the presence of a radiation source. After the test the instrument shall be inspected and it shall be working properly.

## 12 Electromagnetic requirements

### 12.1 General

Special precautions shall be taken in the design of a neutron dose (rate) meter to ensure proper operation in the presence of electromagnetic disturbances, particularly radio-frequency fields. The requirements are given with respect to the lower limit $H_0$ or $\dot{H}_0$ of the effective range of measurement. For each of the electromagnetic tests given in 12.3 to 12.6, the dose equivalent (rate) meter shall be set to the most sensitive range and the dose value set to zero and any deviations due to the tests shall not exceed $\pm 0{,}7\ H_0$ or $\pm 0{,}7\ \dot{H}_0$.

All tests shall be performed for the modes for which the devices are intended to be used, i.e. usually for both the dose equivalent and dose equivalent rate modes.

A suitable radioactive stability check device (for example an encapsulated 2 GBq Am/Be-source) should be fitted to the dose equivalent (rate) meter to produce during the measurements an indication in the most sensitive range, or an indication of seven times the lower limit of the effective range of measurement. The check source shall not interfere with the dose equivalent (rate) meter under test.

### 12.2 Emission of electromagnetic radiation

The instrument shall comply with IEC 62706 concerning radiated emissions for hand-held instruments.

### 12.3 Electrostatic discharge

The instrument shall comply with IEC 62706 concerning electrostatic discharge for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) under standard test conditions. The measurements shall be conducted before, during and after the test. The maximum spurious deviations (both transient and permanent) at the display or data output due to electrostatic discharge shall not exceed $\pm 0{,}7\ H_0$ or $\pm 0{,}7\ \dot{H}_0$ after 10 discharges.

### 12.4 Radio frequency disturbance

The instrument shall comply with IEC 62706 concerning radio frequency for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with and without a radioactive source under standard test conditions. The measurements shall be conducted before, during and after the test.

The maximum spurious deviations (both transient and permanent) of the display or data output due to the electromagnetic fields stated in IEC 62706 shall not exceed $\pm 0{,}7\ H_0$ or $\pm 0{,}7\ \dot{H}_0$.

### 12.5 Magnetic fields

The instrument shall comply with IEC 62706 concerning magnetic fields for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) with and without a radioactive source

under standard test conditions. The measurements shall be conducted before, during and after the test.

The additional spurious deviations (both transient and permanent) of the display or data output due to the magnetic fields stated in IEC 62706 shall not exceed $\pm 0{,}7\ H_0$ or $\pm 0{,}7\ \dot{H}_0$.

### 12.6 Alternating current powered equipment requirements

If the instrument is powered or can be powered by alternating current (AC), the instrument shall comply with IEC 62706 concerning AC line powered equipment requirements for hand-held instruments.

The functionality test shall consist of measurements of the dose equivalent and (or) ambient dose equivalent rate (whichever is applicable or both) under standard test conditions. The measurements shall be conducted before, during and after the test.

The maximum spurious indications (both transient and permanent) of the display or data output due to voltage and frequency fluctuations, surges or oscillatory waves, conducted radiofrequencies shall be less than 10 % of the indication without the disturbances.

No alarms or other outputs shall be activated when the meter or monitor is exposed to the pulses. Battery only operated dose equivalent (rate) meters are excluded from this test.

## 13 Documentation

### 13.1 Operation and maintenance manual

Each instrument shall be supplied with detailed operating instructions, maintenance and technical documentationcontaining full information on

a) assembly construction;
b) assembly function;
c) assembly performance and limitations;
d) modes of operation and instrument handling;
e) use of software (if any) controlling the detection assembly and the stored data;
f) details of the detector and moderator;
g) data on dead times;
h) behaviour in pulsed radiation fields, e.g. the neutron dose (rate) meter is not intended for pulse fields;
i) appropriate information for servicing, alignment and testing;
j) relevant maintenance guidance (see IEC 61187).

### 13.2 Identification certificate

A certificate shall accompany each assembly, giving at least the following information (see IEC 61187):

a) manufacturer's name or registered trade mark;
b) type of assembly and serial number;
c) scale limits for each measuring range;
d) reference source(s) used for calibration;
e) the neutron fluence-to-ambient dose equivalent conversion coefficient for the reference source(s);

f) relative response as a function of neutron energy in the entire energy range;

g) relative response to photon radiation;

h) reference point of the assembly (if necessary dependent on neutron energy) and calibration orientation;

i) detector type and specifications;

j) dimensions and weight of the detection assembly and the complete assembly;

k) neutron energies at which compliance with the angle of incidence requirement has been checked;

l) response as a function of angle of incidence;

m) any hazardous or flammable material of the device;

n) statement that this equipment is tested in accordance with this standard and that the requirements are fulfilled.

### 13.3 Type test report

At request of the purchaser the manufacturer shall provide a report covering the type tests performed in accordance with the requirements of this standard.

**Table 1 – Reference conditions and standard test conditions**

| Influence quantities | Reference conditions (unless otherwise indicated by the manufacturer) | Standard test conditions (unless otherwise indicated by the manufacturer) |
|---|---|---|
| Reference neutron radiation | $^{241}$Am/Be, $^{252}$Cf, $^{252}$Cf ($D_2O$), or D(d,n)$^3$He, T(d,n)$^4$He, T(p,n) and $^7$Li(p,n) accelerator neutron sources | $^{241}$Am/Be, $^{252}$Cf, $^{252}$Cf ($D_2O$), or D(d,n)$^3$He, T(d,n)$^4$He, T(p,n) and $^7$Li(p,n) accelerator neutron sources |
| Dose for:<br>$H^*(10)$ | 100 μSv | 10 μSv to 1 mSv |
| Dose rate for:<br>$\dot{H}^*(10)$ | 10 μSv·h$^{-1}$ | 3 μSv·h$^{-1}$ to 100 μSv·h$^{-1}$ |
| Warm-up time | Stated by manufacturer | Stated by manufacturer |
| Ambient temperature | 20 °C | 18 °C to 22 °C |
| Relative humidity | 65 % | 50 % to 75 % |
| Atmospheric pressure | 101,3 kPa | 86,0 kPa to 106,0 kPa |
| Power supply voltage [a)] | Nominal power supply voltage $U_N$ | Nominal power supply voltage $U_N \pm 1$ % |
| Power supply frequency [a)] | Nominal frequency $f_N$ | Nominal frequency $F_n \pm 1$ % |
| Power supply waveform [a)] | Sinusoidal | Sinusoidal with total harmonic distortion less than 5 % |
| Angle of incidence of radiation | Calibration direction given by manufacturer | Direction given ± 10° |
| 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 assembly | To be stated by the manufacturer | Stated orientation ±5° |
| Assembly controls | Set up for normal operation | Set up for normal operation |
| Contamination by radioactive elements | Negligible | Negligible |

[a)] Only for assemblies which are (or can also be) operated from the mains.

**Table 2 – Radiation characteristics of ambient neutron dose (rate) equivalent meters**

| 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 |
|---|---|---|---|
| Variation of the response due to dose rate | 5 μSv·h$^{-1}$ to 1 Sv·h$^{-1}$ b) | –17 % to +25 % a) | 6.3 |
| Variation of the response due to the neutron energy | Thermal to 50 keV<br>50 keV to 10 MeV<br>Above 10 MeV | Stated by the manufacturer. Recommended relative response is within (0,2 – 8,0)<br>Relative response shall be within (0,5 – 2,0)<br>Stated by the manufacturer. Recommended relative response is within (0,2 – 2,0) | 6.4 |
| Variation of the response due to the angle of incidence | from 0° to 90°<br>from 90° to 180°<br>from –90° to –180° | ±25 %<br>Stated by manufacturer<br>Stated by manufacturer | 6.6 |
| Overload | Ambient dose equivalent rate of 10 % in excess of that specified as the dose rate limit by the manufacturer<br>Ambient equivalent dose 10 times the maximum dose that can be indicated | The indication shall be off-scale on the high side or overload shall be indicated and shall remain so 〚C〉 until unit is reset or is switched off 〈C〛 | 6.7 |
| Response time | Time to reach 90 % of the final value after a sudden change in the ambient dose equivalent rate | <30 s for ambient dose equivalent rates less than 0,1 mSv·h$^{-1}$ b)<br><10 s for ambient dose equivalent rates between 0,1 mSv·h$^{-1}$ and 1 mSv·h$^{-1}$ b)<br><4 s for ambient dose equivalent rates greater than 1 mSv·h$^{-1}$ b) | 6.8 |
| Accuracy of dose rate alarm set to $\dot{H}_a$ c) | $\dot{H}_a \geq$ maximum value of the second least significant order of magnitude | If device is subjected to 0,8 $\dot{H}_a$, alarm shall not be activated for more than 10 % of the test period. If device is subjected to 1,2 $\dot{H}_a$, alarm shall be activated for at least 90 % of the test period. | 6.10 |
| Accuracy of dose alarm set to $H_a$ c) | $H_a \geq$ maximum value of the second least significant order of magnitude | The same limit of variation as for dose rate alarm with values of $H_a$ substituted for $\dot{H}_a$ | 6.11 |
| Response to photon radiation | Ambient dose equivalent rate equal to 10 mSv·h$^{-1}$ from a $^{137}$Cs source | Indication < 0,1 mSv·h$^{-1}$ | 6.12 |
| Additivity of indicated value | For two different irradiation conditions K and L, the relative change in indication is $\Delta H_{imix} = \frac{H_{iK} + H_{iL} + H_{i(K+L)}}{H_{i(K+L)}}$ | The relative change in indication, $\Delta H_{imix}$ shall not exceed ± 0,1 | 7.1 to 7.3 |

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

b) Minimum dose rate value as low as reasonably achievable. If the maximum dose rate specified by the manufacturer for dose measurements is less than 1 Sv·h$^{-1}$, this should be indicated on the neutron dose (rate)meter.

c) $H_a$ and $\dot{H}_a$ are the dose and dose rate alarm setting points.

**Table 3 – Values of $c_1$ and $c_2$ for $w$ different dose rate values and $n$ indications for each dose rate value [8]**

| $w$ | 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 |

Example: For 12 different dose rates and 10 indications taken at every dose rate value, the $c_1$ value becomes $c_1$ = 1,173 and the $c_2$ value becomes $c_2$ = 1,548.

**Table 4 – Electrical and environmental characteristics of ambient dose equivalent (rate) meters**

| Characteristic under test or influence quantity | (Minimum) rated range of influence quantity | Limits of variation of the relative response or of the deviation | Sub-clause |
|---|---|---|---|
| Zero drift | Over a period of 300 min continuous operation (after warm up of 30 min): | no more than ± 0,2 $H_0$ or ± 0,2 $\dot{H}_0$ | 9.1 |
| Warm-up time | Not applicable | Time to read within ±10 % of the final value under reference conditions to be within limits stated by manufacturer | 9.2 |
| Power supplies<br>a) Primary batteries<br>b) Mains operation (if applicable) [a)] | After 40 h intermittent use<br>From 88 % $U_N$ to 110 % $U_N$<br>From 47 (57) Hz to 53 (63) Hz | ±10 % of initial value<br>±10 % of initial value<br>±10 % of initial value | 9.3<br>9.4<br>9.4 |
| Ambient temperature | According to IEC 62706 for hand-held instruments:<br>–20 °C to +50 °C | <br>–15 % to +22 % | 10.2 |
| Temperature shock | According to IEC 62706 for hand-held instruments:<br>+20 °C to +50 °C<br>+20 °C to –20 °C | <br>–15 % to +22 %<br>–15 % to +22 %<br>The time required to become functional shall be stated by manufacturer | 10.3 |
| Relative humidity | According to IEC 62706<br>up to 93 % relative humidity at 35 °C | <br>–15 % to +22 % [b)] | 10.4 |
| Sealing | According to IEC 62706 for hand-held instruments:<br>IP 53 | Precautions to be stated to prevent ingress of moisture | 10.6 |
| Storage and transport | –25 °C to +50 °C<br>for three months | To operate within specification after unpacking and reaching ambient temperature | 10.7 |

a) $U_N$ is the nominal voltage of the main AC.

b) Limit of variation from the indication at 35 °C and reference humidity.

**Table 5 – Maximum values of deviation due to mechanical requirements**

| Influence quantity or instrument parameter | Minimum rated range of influence quantity | Test according to | Maximum permitted value for deviation, $D_p$, for whole rated range | Sub-clause |
|---|---|---|---|---|
| Drop | Drop from 30 cm onto hardwood | IEC 62706 | ± 5 % of values before the test | 11.2 |
| Vibration | 0,01 $g^2 \cdot Hz^{-1}$ with end points of 5 Hz and 500 Hz | IEC 62706 | ± 5 % of values before the test | 11.3 |
| Microphonics | sharp impacts at 0,2 J | IEC 62706 | ± 5 % of values before the test | 11.4 |
| Mechanical shock | 10 shocks pulses of 50 g peak acceleration | IEC 62706 | ± 5 % of values before the test | 11.5 |

**Table 6 – Maximum values of deviation due to electromagnetic disturbances**

| Influence quantity or instrument parameter | Minimum rated range of influence quantity | Test according to | Maximum value of deviation [a] | Sub-clause |
|---|---|---|---|---|
| Emission of electromagnetic radiation | Not applicable | IEC 62706 | Not to exceed values in Table 7 | 12.2 |
| Electrostatic discharge, charging voltage | 0 kV to ± 8 kV air discharge<br>0 kV to ± 6 kV contact discharge | IEC 62706 | ± 0,7 $H_0$ or ± 0,7 $\dot{H}_0$ | 12.3 |
| Radiofrequency disturbance | 80 MHz to 6 GHz at 10 V $m^{-1}$ | IEC 62706 | ± 0,7 $H_0$ or ± 0,7 $\dot{H}_0$ | 12.4 |
| Magnetic fields | 80 A/m at 50 Hz or 60 Hz magnetic field | IEC 62706 | ± 0,7 $H_0$ or ± 0,7 $\dot{H}_0$ | 12.5 |
| AC powered instruments[b] | | | | |
| – voltage and frequency fluctuations | –12 % to +10 % of nominal voltage<br>47 to 53 Hz / 57 to 63 Hz | | | |
| – immunity from conducted RF | 150 kHz to 80 MHz at 140 dB (μV) 80 % amplitude modulated with 1 kHz | IEC 62706 | < 10 % of the indication without the disturbance | 12.6 |
| – surges and ring waves | 2 kV ring wave<br>1,2/50 μs and 8/20 μs at 2 kV combination wave | | | |

[a] $H_0$ is the lower limit of the effective range of measurement.

[b] If applicable.

**Table 7 – Emission frequency range**

| MHz | Field strength (peak) μV/m |
|---|---|
| 30 to 88 | 100 |
| 88 to 216 | 150 |
| 216 to 960 | 200 |
| > 960 | 500 |

**Table 8 – Symbols and abbreviations used in this standard**

| Symbol | Explanation |
|---|---|
| AC | alternating current |
| CRC-16 | algorithm to detect data changes based on the check sum over all bytes in the data package [7] |
| $D$ | deviation |
| $\Phi$ | neutron fluence |
| $\dot{\Phi}$ | neutron fluence rate |
| g | free-fall acceleration |
| $H^*(10)$ | ambient dose equivalent |
| $\dot{H}^*(10)$ | ambient dose equivalent rate |
| $H_0$ | lower limit of effective range of measurement for dose equivalent |
| $\dot{H}_0$ | lower limit of effective range of measurement for ambient dose equivalent rate |
| $\dot{H}_\mathrm{i}^*(10)$ | initial indicated value of ambient dose equivalent rate |
| $\dot{H}_\mathrm{f}^*(10)$ | final indicated value of ambient dose equivalent rate |
| $H_\mathrm{a}$ | dose alarm setting |
| $\dot{H}_\mathrm{a}$ | dose rate alarm setting |
| $h\phi$ | neutron fluence-to-ambient dose equivalent conversion coefficient |
| $H_\mathrm{i}$ | indicated value of the quantity |
| $H_\mathrm{t}$ | conventional value of the quantity |
| $\mathrm{H_{tK}}$ | conventional quantity value for irradiation condition K (type of radiation, neutron energy or angle of incidence) |
| $\mathrm{H_{iK}}$ | indicated value for $\mathrm{H_{tK}}$ |
| $H_{\mathrm{t\,(K+L)}}$ | conventional quantity value for simultaneous irradiation under two irradiation conditions K and L |
| $H_{\mathrm{i\,(K+L)}}$ | indicated value for $H_{\mathrm{t\,(K+L)}}$ |
| $\Delta H_\mathrm{imix}$ | relative change in indication with respect to simultaneous irradiation with 2 different types of radiation K and L (or neutron energies, or angles of incidence) |
| $\mathrm{S_0}$ | input electrical signal to be injected as to produce indicated value $\dot{H}_0(10)$ |
| $\mathrm{S_1}$ | input electrical signal to be injected as to produce indicated value $\dot{H}_1(10)$ |
| $U_\mathrm{nom}$ | nominal battery voltage |
| $\dot{G}_\mathrm{nom}$ | dose meter indication under $U_\mathrm{nom}$ battery voltage |
| $\dot{G}_\mathrm{low}$ | dose meter indication when “low battery” indication is displayed |
| $\mathrm{I_{low}}$ | supply battery current when dose meter indication is $\dot{G}_\mathrm{low}$ |
| $\mathrm{Q_{nom}}$ | nominal capacity of battery |
| IPclassification | ingress protection rating according to IEC 60529 |
| $R_0$ | reference response |
| RF | radio frequency |
| U | uncertainty |
| $\mathrm{U_{rel}}$ | relative uncertainty of measurement |
| $U_\mathrm{N}$ | nominal voltage of AC power line or of supply voltage |
| v | coefficient of variation |
| WELMEC | is a cooperation between the legal metrology authorities of the Member States of the European Union and EFTA. WELMEC Guides provide guidance to manufacturers of measuring instruments which is purely advisory. |

# Annex A
(informative)

# Neutron fluence-to-ambient dose equivalent conversion coefficients

**Table A.1 – Neutron fluence-to-ambient dose equivalent conversion coefficients for mono-energetic neutrons ([5],[6])**

| Neutron energy<br>MeV | Neutron fluence-to-ambient dose equivalent conversion coefficients $H^*(10)/\Phi$<br>pSv·cm$^{-2}$ |
|---|---|
| $1{,}00 \times 10^{-9}$ | 6,60 |
| $1{,}00 \times 10^{-8}$ | 9,00 |
| $2{,}53 \times 10^{-8}$ | 10,6 |
| $1{,}00 \times 10^{-7}$ | 12,9 |
| $2{,}00 \times 10^{-7}$ | 13,5 |
| $5{,}00 \times 10^{-7}$ | 13,6 |
| $1{,}00 \times 10^{-6}$ | 13,3 |
| $2{,}00 \times 10^{-6}$ | 12,9 |
| $5{,}00 \times 10^{-6}$ | 12,0 |
| $1{,}00 \times 10^{-5}$ | 11,3 |
| $2{,}00 \times 10^{-5}$ | 10,6 |
| $5{,}00 \times 10^{-5}$ | 9,90 |
| $1{,}00 \times 10^{-4}$ | 9,40 |
| $2{,}00 \times 10^{-4}$ | 8,90 |
| $5{,}00 \times 10^{-4}$ | 8,30 |
| $1{,}00 \times 10^{-3}$ | 7,90 |
| $2{,}00 \times 10^{-3}$ | 7,70 |
| $5{,}00 \times 10^{-3}$ | 8,00 |
| $1{,}00 \times 10^{-2}$ | 10,5 |
| $2{,}00 \times 10^{-2}$ | 16,6 |
| $3{,}00 \times 10^{-2}$ | 23,7 |
| $5{,}00 \times 10^{-2}$ | 41,1 |
| $7{,}00 \times 10^{-2}$ | 60,0 |
| $1{,}00 \times 10^{-1}$ | 88,0 |
| $1{,}50 \times 10^{-1}$ | 132 |
| $2{,}00 \times 10^{-1}$ | 170 |
| $3{,}00 \times 10^{-1}$ | 233 |
| $5{,}00 \times 10^{-1}$ | 322 |
| $7{,}00 \times 10^{-1}$ | 375 |
| $9{,}00 \times 10^{-1}$ | 400 |
| 1,00 | 416 |
| 1,20 | 425 |

| Neutron energy<br><br>MeV | Neutron fluence-to-ambient dose equivalent conversion coefficients $H^*(10)/\Phi$<br>$pSv \cdot cm^{-2}$ |
|---|---|
| 2,00 | 420 |
| 3,00 | 412 |
| 4,00 | 408 |
| 5,00 | 405 |
| 6,00 | 400 |
| 7,00 | 405 |
| 8,00 | 409 |
| 9,00 | 420 |
| 10,0 | 440 |
| 12,0 | 480 |
| 14,0 | 520 |
| 15,0 | 540 |
| 16,0 | 555 |
| 18,0 | 570 |
| 20,0 | 600 |

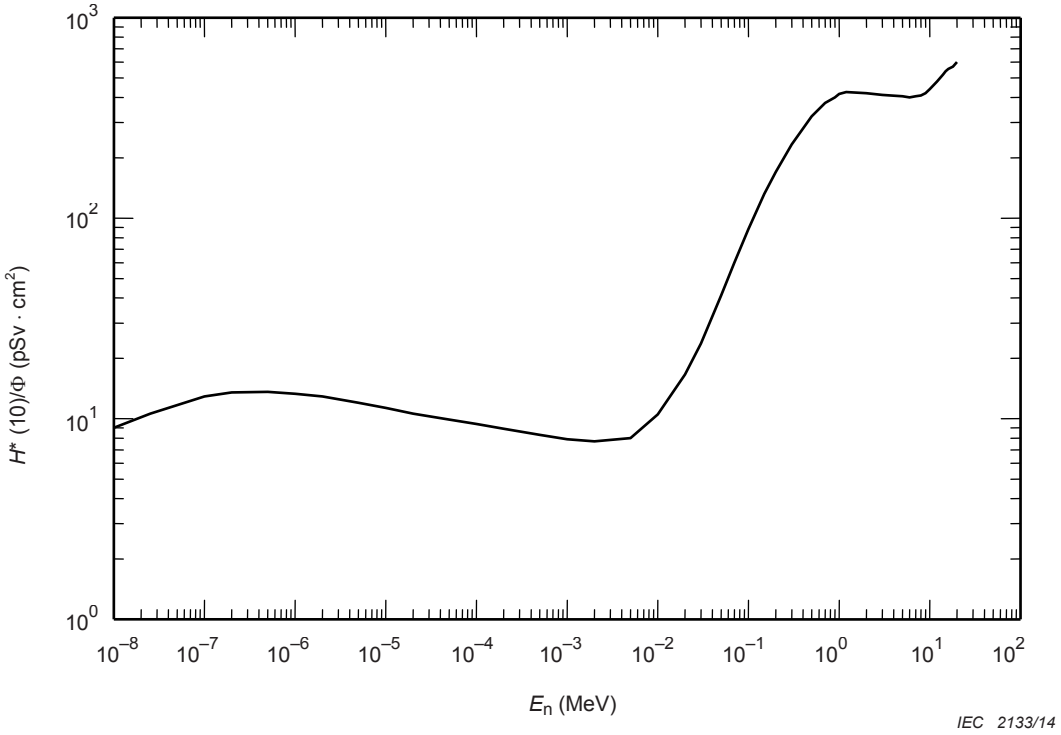


**Figure A.1 – Neutron fluence-to-ambient dose equivalent conversion coefficients for mono-energetic neutrons [5]**

**Table A.2 – Neutron fluence-to-ambient dose equivalent conversion coefficients for the neutron reference radiation sources ([5] and ISO 8529-3)**

| Source | Fluence averaged neutron energy<br>MeV | Averaged neutron fluence-to-dose equivalent conversion coefficients<br>$H^*(10)/\Phi$<br>$pSv \cdot cm^{-2}$ |
|---|---|---|
| $^{252}Cf$ | 2,13 | 385 |
| $^{252}Cf(D_2O)$moderated | 0,55 | 105 |
| $^{241}$Am-Be ($\alpha$,n) | 4,16 | 391 |
| D(d,n)$^3$He | 2,8 | 413 |
| T(d,n)$^4$He | 14,8 | 536 |
| NOTE Averaged neutron energy and averaged neutron fluence-to-ambient dose conversion coefficients in this table are provided for D(d,n)$^3$He and T(d,n)$^4$He neutrons emitted at 0° degree with respect to the direction of the incident deuterons. | | |

# Bibliography

[1] IAEA Compendium of Neutron Spectra and Detector Responses for Radiation Protection Purposes, *Supplemental to Technical Report Series No. 318, Technical Reports Series N. 403*, International Atomic Energy Agency, Vienna 2001

[2] ICRP Publication 74:1996, "Conversion Coefficients for use in Radiological Protection against External Radiation", *Annals of the ICRP*, Vol. 26, 2/4

[3] JCGM 100:2008, *Guide to the expression of uncertainty in measurement (GUM)*

[4] ICRU Report 51:1993, *Quantities and Units in Radiation Protection Dosimetry*

[5] ICRU Report 57:1998, *Conversion Coefficients for Use in Radiation Protection Against External Radiation*

[6] ICRU Report 66:2001, *Determination of Operational Dose Equivalent Quantities For Neutrons*

[7] WELMEC:2012, *WELMEC 7.2, Software Guide: Measuring Instruments Directive 2004/22/EC, Issue 5*, downloadable from http://www.welmec.org/latetest/guides/72.html

[8] Brunzendorf, J. and Behrens, R., "How to type test the coefficient of variation of an indication", *Radiation Protection Dosimetry*, Vol. 123, pp. 21-31,2007

[9] IEC 60050-395: *International Electrotechnical Vocabulary – Part 395: Nuclear instrumentation – Physical phenomena, basic concepts, instruments, systems, equipment and detectors*

[10] IEC TR 62461, *Radiation protection instrumentation – Determination of uncertainty in measurement*

[11] ISO 4037-1:1996, *X and gamma reference radiations for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods*

[12] ISO 4037-2:1997, *X and gamma reference radiations for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 2: Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV*

[13] ISO 4037-3:1999, *X and gamma reference radiations for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*

[14] JCGM 200:2008, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM) 3rd Edition*

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