IEC 61005

Edition 3.0 2014-07

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

## Radiation protection instrumentation – Neutron ambient dose equivalent (rate) meters



## Instrumentation pour la radioprotection – Appareils de mesure de l'équivalent de dose ambiant neutron (ou de son débit d'équivalent de dose)



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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- withdrawn,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 realistic neutron fields, however, is such that the response deviations in different energy ranges tend to offset each other. Consequently, the response in realistic fields 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.

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1 Numbers in square brackets refer to the Bibliography.

**3.1.3**
**ambient dose equivalent rate**
$\dot{H}^*(10)$
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 $\overline{H}$ of a set of n indications $H_j$. It is given by the following formula:



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

**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

$$D = H_i - H_r$$

Where

$H_i$ is the indicated value under the effect of an influence quantity, and

$H_r$ 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**
**minimal 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 minimal 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.