

Radiation protection instrumentation — Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation

The European Standard EN 60846:2004 has the status of a
British Standard

ICS 13.280

National foreword

This British Standard is the official English language version of EN 60846:2004. It was derived by CENELEC from IEC 60846:2002.

The CENELEC common modifications have been implemented at the appropriate places in the text and indicated by tags **[C]** **<C>**.

The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement, which has the responsibility to:

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**Radiation protection instrumentation –
Ambient and/or directional dose equivalent (rate) meters
and/or monitors for beta, X and gamma radiation
(IEC 60846:2002, modified)**

Instrumentation pour la radioprotection -
Instruments pour la mesure et/ou
la surveillance de l'équivalent de dose
(ou du débit d'équivalent de dose)
ambiant et/ou directionnel
pour les rayonnements bêta, X et gamma
(CEI 60846:2002, modifiée)

Strahlenschutz-Messgeräte –
Umgebungs- und Richtungs-
Äquivalentdosis(leistungs)-Messgeräte
und -Monitore für Beta, Röntgen- und
Gammastrahlung
(IEC 60846:2002, modifiziert)

This European Standard was approved by CENELEC on 2004-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

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

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Foreword

The text of the International Standard IEC 60846:2002, prepared by SC 45B, Radiation protection instrumentation, of IEC TC 45, Nuclear instrumentation, together with the common modifications prepared by the CENELEC BTTF 111-3, Instrumentation for ionizing radiation measurement and protection, was submitted to the formal vote and was approved by CENELEC on 2004-10-01.

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with the EN have to be withdrawn (dow) 2007-10-01

Clauses, subclauses, tables and figures which are additional to those in IEC 60846 are prefixed "Z".

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60846:2002 was approved by CENELEC as a European Standard with agreed common modifications.

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RADIATION PROTECTION INSTRUMENTATION – AMBIENT AND/OR DIRECTIONAL DOSE EQUIVALENT (RATE) METERS AND/OR MONITORS FOR BETA, X AND GAMMA RADIATION

1 Scope and object

This International Standard applies to dose equivalent (rate) meters and/or monitors for the measurement of ambient dose equivalent (rate) and/or directional dose equivalent (rate) from external beta, X and gamma radiation, as recommended in ICRU Report 47¹.

NOTE 1 If both quantities, ambient dose equivalent and directional dose equivalent are meant, the term dose equivalent may be used as an abbreviation.

It applies directly to dose equivalent (rate) meters intended for the determination of the dose equivalent or dose equivalent rate from external beta and/or X and gamma radiation of energies up to 10 MeV for radiation protection purposes.

In this document, the expression "dose equivalent (rate)" is used when the provisions apply to both the measurement of dose equivalent and the measurement of dose equivalent rate.

NOTE 2 It does not apply to medical radiology which is within the scope of technical committee 62, where the conditions of radiation exposure may be extremely inhomogeneous, but precisely known.

NOTE 3 It does not apply directly to instruments intended to be worn by an individual for the purpose of estimating the radiation dose received by that individual.

The object of this standard is to specify the design requirements and the performance characteristics of dose equivalent (rate) meters intended for the determination of ambient dose equivalent (rate) and directional dose equivalent (rate) as defined in ICRU Report 47¹.

Accordingly, this standard specifies:

- a) general characteristics, the functions and performance characteristics of dose equivalent (rate) meters;
- b) the methods of test to be used to determine compliance with the requirements of this standard.

¹ ICRU Report 47: 1992, *Measurements of Dose Equivalents from External Photon and Electron Radiations*, International Commission on Radiation Units and Measurements, 7910 Woodmont Avenue, Bethesda, Maryland 20814-3095, U.S.A.

2 Normative references

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

IEC 60038:1983, *IEC standard voltages*

Amendment 1 (1994)

Amendment 2 (1997)

IEC 60050-151: 2001, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050-393:1996, *International Electrotechnical Vocabulary (IEV) – Chapter 393: Nuclear instrumentation: Physical phenomena and basic concepts*

IEC 60050-394:1995, *International Electrotechnical Vocabulary (IEV) – Chapter 394: Nuclear instrumentation: Instruments*

IEC 60068-2-27:1987, *Environmental testing – Part 2: Tests. Test Ea and guidance: Shock*

IEC 60086 (all parts): *Primary batteries*

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test*

IEC 61000-4-3:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 3: Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test*

Amendment 1 (2000)

Amendment 2 (2001)

IEC 61000-4-5:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test*

IEC 61000-4-6:1996, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 6: Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8:1993, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 8: Power frequency magnetic field immunity test*

IEC 61000-4-11:1994, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 11: Voltage dips, short interruptions and voltage variations immunity tests*

IEC 61000-6-2:1999, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

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

ISO 4037-1:1996, *X and gamma reference radiation for calibrating dosimeters and dose-rate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods*

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

ISO 4037-3:1999, *X and gamma reference radiation for calibrating dosimeters and dose-rate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosimeters and the measurement of their response as a function of energy and angle of incidence*

ISO 6980:1996, *Reference beta radiations for calibrating dosimeters and dose-rate meters and for determining their response as a function of beta-radiation energy*

3 Terminology

3.1 General

Except as specified below, all technical terms are as defined in IEC 60050, particularly for radiation quantities and dosimetric terms in IEC 60050-393 and IEC 60050-394. For the purpose of this International Standard, the following definitions apply.

3.2 Definitions

3.2.1

conventionally true value of dose equivalent (rate)

the best estimate of the true dose equivalent (rate) used for the calibration of equipment. This value and its uncertainty are determined from a secondary or a primary standard, or by a reference instrument which has been calibrated against a secondary or primary standard.

3.2.2

error of indication of a dose equivalent (rate) meter

difference between the indicated value of dose equivalent (rate), H_i , and the conventionally true value of that quantity, H_t , at the point of measurement. It is expressed as $H_i - H_t$.

3.2.3

relative error of an indication of a dose equivalent (rate) meter

ratio of error of indication of the measured dose equivalent (rate) to the conventionally true value of the dose equivalent (rate). It may be expressed as a percentage:

$$I = \frac{H_i - H_t}{H_t} \times 100 \%$$

3.2.4

relative intrinsic error of a dose equivalent (rate) meter

relative error of the indication of a dose equivalent (rate) meter with respect to dose equivalent (rate) when subjected to a specified reference radiation under specified reference conditions

3.2.5

response of a dose equivalent (rate) meter

ratio of the dose equivalent (rate) meter's indicated value to the conventionally true value

3.2.6**coefficient of variation**

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

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

3.2.7**reference point of a dose equivalent (rate) meter**

physical mark or marks on the outside of the dose equivalent (rate) meter used to position it at the point of measurement or the point of test

3.2.8**point of test of a dose equivalent (rate) meter**

point at which the conventionally true value is determined and at which the reference point of the dose equivalent (rate) meter is placed for calibration and test purposes

3.2.9**effective range of measurement of a dose equivalent (rate) meter**

range of values of the quantity to be measured over which the performance of a dose equivalent (rate) meter meets the requirements of this standard

3.2.10**rated range of a dose equivalent (rate) meter**

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

3.2.11**minimum rated range of a dose equivalent (rate) meter**

least range of an influence quantity or instrument parameter being specified over which the dose equivalent (rate) meter shall operate within the specified limits of variation in order to comply with this standard

3.2.12**standard test values**

a 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 Under standard test conditions, influence quantities and instrument parameters have their standard test values.

3.2.13**reference orientation of a dose equivalent (rate) meter**

orientation of the dose equivalent (rate) meter with respect to the direction of the incident radiation during calibration

3.2.14**dose equivalent (rate) meter**

assembly intended to measure or evaluate the dose equivalent (rate)

☐ 3.2.Z1**maximum dose equivalent rate (for dosemasters)**

the dose rate, specified by the manufacturer, above which the dose reading is no longer within the requirements of this standard. ☐

3.3 Test nomenclature

3.3.1

qualification tests

tests which are performed in order to verify that the requirements of a specification are fulfilled. Qualification tests are sub-divided into type tests and routine tests as defined below.

3.3.2

type test

conformity testing on the basis of one or more specimens of a product representative of the production [IEV 151-04-15, modified]

3.3.3

routine test

a test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria [IEV 151-04-16]

3.3.4

acceptance test

a contractual test to prove to the customer that the device meets certain conditions of its specification [IEV 151-04-20]

3.3.5

supplementary tests

tests intended to provide supplementary information on certain characteristics of the dose equivalent (rate) meters

3.4 Quantities and units

3.4.1

SI units

The units of the international system (SI)² are used.

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

3.4.2

units other than SI units

The following units are used in addition to the SI units:

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

3.4.3

sievert

the SI unit of dose equivalent is $\text{J} \cdot \text{kg}^{-1}$ and has been given the special name sievert (Sv)

$$1 \text{ Sv} = 1 \text{ J} \cdot \text{kg}^{-1}$$

3.4.4

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 Bureau International des Poids et Mesures: *The International System of Units (SI)*, 7th edition, 1998

3.4.5**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

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

The SI unit of ambient dose equivalent rate is the sievert per second ($\text{Sv}\cdot\text{s}^{-1}$). Units of ambient dose equivalent rate are any quotient of the sievert or its decimal multiples or submultiples by a suitable unit of time (e.g. $\text{mSv}\cdot\text{h}^{-1}$).

3.4.6**directional dose equivalent $H'(0,07)$**

dose equivalent at a point in a radiation field that would be produced by the corresponding expanded field in the ICRU sphere at a depth of 0,07 mm, on a radius in a specified direction

3.4.7**directional dose equivalent rate $\dot{H}'(0,07)$**

ratio of $dH'(0,07)$ by dt , where $dH'(0,07)$ is the increment of directional dose equivalent in the time interval dt

$$\dot{H}'(0,07) = \frac{dH'(0,07)}{dt}$$

The SI unit of directional dose equivalent rate is the sievert per second ($\text{Sv}\cdot\text{s}^{-1}$). Units of directional dose equivalent rate are any quotient of the sievert or its decimal multiples or submultiples by a suitable unit of time (e.g. $\text{mSv}\cdot\text{h}^{-1}$).

NOTE 1 The ICRU sphere (ICRU Report 33, 1980) is a 30 cm diameter, tissue-equivalent sphere with a density of $1\text{ g}\cdot\text{cm}^{-3}$.

NOTE 2 In defining these quantities, it is useful to stipulate certain radiation fields that are derived from the actual radiation field. The terms "expanded" and "aligned" are used to characterize these derived radiation fields. In the *expanded field*, the fluence and its angular and energy distribution are the same throughout the volume of interest as in the actual field at the point of reference. In the *aligned and expanded field*, the fluence and its energy distribution are the same as in the expanded field but the fluence is unidirectional.

NOTE 3 A dose equivalent (rate) meter that has an isotropic response and is calibrated in terms of $H^*(10)$ will measure $H^*(10)$ in any radiation fields that are uniform over the dimensions of the dose equivalent (rate) meter.

NOTE 4 When the word "tissue" is used in this standard, the specification of soft tissue given in ICRU Report 39 (1985) is implied. The mass composition of soft tissue is taken as: 76,2 % O; 10,1 % H; 11,1 % C; 2,6 % N. Trace elements are generally not considered important for dosimetric purposes and have been ignored.

NOTE 5 The specifications of the dose equivalent (rate) to be measured refer only to the specification of the quantity to be indicated by ambient and directional dose equivalent (rate) meters and are not in any way intended as a specification of the detector assemblies themselves. The sphere is only required for the conceptual definition of the quantities' ambient and directional dose equivalent and it is perfectly permissible to speak of the ambient and directional dose equivalent at any point in a radiation field without the sphere being present. In effect, it specifies the value of the quantity to be indicated at any point in any given radiation field, that is, the value against which the indication of the dose equivalent (rate) meter should be compared for calibration purposes in assessing its compliance with the various performance characteristics specified in the standard. The methods used to meet the requirements of this standard such as the type and design of the radiation detection sub-assembly itself are entirely at the discretion of the designer. As an example, a Geiger-Müller tube detector may, by the choice of suitable external filters, be designed to indicate an ambient dose equivalent (rate) over a certain range of X and gamma radiation energies. In this case, the detector would not, for example, require a wall thickness of $1\,000\text{ mg cm}^{-2}$ or need to be mounted on a 30 cm diameter sphere; the requirement is only that the indication of the dose equivalent (rate) meter shall be the same, within the limits of variation permitted in this standard, as the value at the point of measurement of the ambient dose equivalent (rate), $H^*(10)$.

NOTE 6 The ambient dose equivalent at a point in a radiation field of any angular distribution is the value that would have occurred had that same fluence and energy distribution of radiation been present as a parallel beam (aligned). This means that the value of the ambient dose equivalent at a point is independent of the angular distribution of the radiation field. This implies that a dose equivalent (rate) meter to measure ambient dose equivalent should have an isotropic response over a solid angle of 4π steradians. Directional dose equivalent is of concern for radiation of low penetrating power for which the body, if present, would provide shielding over the

hemisphere. Accordingly, the response of a dose equivalent (rate) meter for the measurement of directional dose equivalent should be restricted to a solid angle of 2π steradians and should allow for backscatter from material behind the detector of radiation incident on the front. The value of the directional dose equivalent will decrease as the angle of incidence of the radiation is increased, relative to the reference orientation, due to the increasing path length of the radiation, in those portions of the sphere near to its surface. The requirements for the angular response of dose equivalent (rate) meters are based on these considerations.

NOTE 7 The ambient dose equivalent (rate), used for the monitoring of strongly penetrating radiation, is not an appropriate quantity for any beta radiation even that which is nominally penetrating (ICRU Report 47, 1992).

NOTE 8 When the term dose equivalent alone is used in this standard, the quantities ambient dose equivalent and directional dose equivalent are implied.

4 General characteristics of ambient and directional dose equivalent (rate) meters

4.1 General

4.1.1 Indication

The indications of the dose equivalent (rate) meter shall be in units of dose equivalent or dose equivalent rate, for example millisieverts or millisieverts per hour, respectively.

4.1.2 Read-out

The changing of measuring range and read-out scale shall be simultaneous and shall be clearly displayed. All scales shall be readable under normal lighting conditions.

4.1.3 Dose equivalent (rate) meter labels and markings

A dose equivalent (rate) meter for the measurement of beta, X and gamma dose equivalent (rate) shall be labelled with a specific indication of its intended use (type of radiation (e.g. X and gamma radiation, beta radiation), effective range of measurement and measuring quantity ($H^*(10)$, $H'(0,07)$), combined rated ranges of energy and angle of radiation incidence).

The dose equivalent (rate) meter shall have a reference point (see 3.2.7). The reference point for calibration and test purposes shall be indicated on the outside of the dose equivalent (rate) meter.

4.1.4 Dose equivalent and dose equivalent rate range

The implementation of the ICRP recommendations requires the determination of dose equivalent rate over a wide range of values. Under some circumstances, dose equivalent rates as high as $10 \text{ Sv}\cdot\text{h}^{-1}$ require measurement. At the other extreme, dose equivalent rates as low as $0,1 \mu\text{Sv}\cdot\text{h}^{-1}$ could be obtained (see ICRU Report 20). For many applications, the dose equivalent rates of interest are within the range from approximately $1 \mu\text{Sv}\cdot\text{h}^{-1}$ to $10 \text{ m Sv}\cdot\text{h}^{-1}$.

4.1.5 Effective range of measurement

The effective range of measurement shall be not less than the following:

- a) for dose equivalent (rate) meters with an analogue type of display (e.g. linear or logarithmic) from 10 % to 100 % of the scale maximum angular deflection on each scale range;
- b) for dose equivalent (rate) meters with a digital display, from the first non-zero 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 199,9, the effective range shall extend from 1,0 to 199,9);

- c) for dose equivalent (rate) meters with a digital and scientific display (e.g. $x,yz E \pm ab$) the mantissa shall have two digits at least (for instance 1,0 to 9,9). The manufacturer shall define the effective range of measurement (for instance 1,0 E-7 to 9,9 E-2 with the unit Sv·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 ranges of measurement.

When the test methods do not extend over the whole of the 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. Supplementary tests shall be agreed between the purchaser and the seller.

4.1.6 Minimum range of measurement

The minimum effective range of measurement of dose equivalent rate shall cover at least three orders of magnitude. The minimum effective range of dose equivalent shall cover at least four orders of magnitude and shall include 1 mSv.

Dose equivalent (rate) meters and/or monitors intended to be used in emergency situations shall be capable of measuring dose equivalent rates over the whole range from 100 µSv·h⁻¹ to 10 Sv·h⁻¹. If integrating capability is provided, the range shall be at least from 100 µSv to 2 Sv.

4.1.7 Alarm levels

The visual and/or audible alarms (if provided) for dose equivalent rate and/or dose equivalent should be pre-settable.

It shall be possible to silence the audible alarm as necessary.

It shall be possible to set the dose equivalent alarm either to any value over the effective range of measurement or at least one value in each order of magnitude of this range, for example 3 µSv, 30 µSv, 300 µSv, 3 mSv, 30 mSv, and 300 mSv.

It shall be possible to set the dose equivalent rate alarm either to any value over the effective range of measurement or at least one fixed value in each order of magnitude of this range, for example 3 µSv·h⁻¹, 30 µSv·h⁻¹, 300 µSv·h⁻¹, 3 mSv·h⁻¹, 30 mSv·h⁻¹, and 300 mSv·h⁻¹.

The frequency of the audible alarm should be within the range of 1 000 Hz to 3 000 Hz. Where an intermittent alarm is provided, the signal interval shall not exceed 2 s. The A-weighted sound level should not exceed 100 dBA at 30 cm from the alarm source and shall be at least 75 dBA at that point.

NOTE The manufacturer should indicate whether the setting of the alarm point is to be done with the aid of a tool, by software interface or manually.

4.1.8 Additional indication

Indication shall be given of operation conditions in which the accumulation of dose equivalent is not accurate (within the specifications of this standard), for example low battery, detector failure and in high dose equivalent rate fields.

4.1.9 Failure operation of indication

A provision to test for failure of the display shall be installed.