

Radiation protection instrumentation — In vivo counters — Classification, general requirements and test procedures for portable, transportable and installed equipment

The European Standard EN 61582:2006 has the status of a
British Standard

ICS 13.280

National foreword

This British Standard is the official English language version of EN 61582:2006. It was derived by CENELEC from IEC 61582:2004.

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

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 63 and a back cover.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2006

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ISBN 0 580 48479 3

Amendments issued since publication

Amd. No.	Date	Comments

**Radiation protection instrumentation -
In vivo counters -
Classification, general requirements and test procedures
for portable, transportable and installed equipment
(IEC 61582:2004, modified)**

Instrumentation pour la radioprotection -
Systèmes de mesure in vivo -
Classification, exigences générales
et procédures d'essai pour les appareils
portables, mobiles ou à poste fixe
(CEI 61582:2004, modifiée)

Strahlenschutz-Messgeräte -
Einrichtungen für die
in-vivo-Überwachung -
Ganz- und Teilkörperzähler -
Klassifizierung, allgemeine Anforderungen
und Prüfverfahren für tragbare,
transportable und festinstallierte
Einrichtungen
(IEC 61582:2004, modifiziert)

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CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of the International Standard IEC 61582:2004, prepared by SC 45B, Radiation protection instrumentation, of IEC TC 45, Nuclear instrumentation, together with common modifications prepared by the CENELEC BTTF 111-3, Nuclear instrumentation and radiation protection instrumentation, was submitted to the formal vote and was approved by CENELEC as EN 61582 on 2006-02-01.

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2007-02-01 |
| – latest date by which the national standards conflicting with the EN have to be withdrawn | (dow) | 2009-02-01 |

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61582:2004 was approved by CENELEC as a European Standard with agreed common modifications.

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RADIATION PROTECTION INSTRUMENTATION – IN VIVO COUNTERS – CLASSIFICATION, GENERAL REQUIREMENTS AND TEST PROCEDURES FOR PORTABLE, TRANSPORTABLE AND INSTALLED EQUIPMENT

1 Scope and object

This International Standard specifies the classification, general design requirements, performance characteristics and test procedures for in vivo counting systems for detecting trace amounts of radionuclides in the bodies of persons working in nuclear power plants, laboratories and facilities handling radionuclides, and inhabitants living on territory which may be contaminated by either naturally occurring or artificial radionuclides. The purpose is to determine the dose equivalent to organs and the effective dose of internal radiation for the whole body.

This standard is applicable both to equipment with spectroscopic capabilities and instruments for rapid screening for gross internal contamination only.

This standard is applicable to instruments for the monitoring of certain critical organs (for example, lungs, thyroid gland, etc.) as well as instruments for monitoring the whole body.

The standard applies to equipment for the measurement of the activity of gamma-emitting radionuclides in humans in order to determine the committed dose equivalent due to internal contamination in accordance with the recommendations of the ICRP 60 and ICRP 61.

The requirements of the standard are applicable to the installed apparatus, to vehicle-mounted equipment and to portable instruments. However, Annex B defines the additional mechanical and environmental performance requirements and the additional testing required for transportable and portable assemblies. The general and radiological requirements of all types of in vivo counters are included in this standard.

Depending on the type of instrument and the organ to be checked, measurement geometry may require the subject of the monitoring procedure to stand, sit, or lie.

The detection assembly includes one or more radiation detector. Normally, these are shielded-scintillation or semi-conductor detectors. Where identification of the location of contamination is required, the detectors may be collimated.

The measurement assembly includes functional units for the processing of signals from the detection assembly as well as units for the display of the measured activity.

For the measurement of body mass a built-in weighing machine may be used.

The standard specifies general types, specific measuring characteristics, main test procedures, electrical and mechanical characteristics C *Text deleted* C, as well as the requirements related to background radiation of the environment.

This equipment is not intended for the determination of external contamination of the human body or the clothing of personnel.

This standard is not applicable to equipment such as radiation detectors intended for introduction into the human body.

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.

2.1 International standards

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

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

IEC 60068-2-1, *Environmental testing – Part 2: Tests. Tests A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2: Tests. Tests B: Dry heat*

IEC 60068-2-6: *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2: Tests. Test N: Change of temperature.*

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

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60721-3-5: *Classification of environmental conditions – Part 3-5: Classification of groups of environmental parameters and their severities – Ground vehicle installation.*

IEC 60721-3-7: *Classification of environmental conditions – Part 3-7: Classification of groups of environmental parameters and their severities – Portable and non-stationary use.*

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

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

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

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

IEC 61000-4-12:1995, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Oscillatory waves immunity test*

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

IEC 61276:1994, *Nuclear instrumentation – Guidelines for selection of metrologically supported nuclear radiation spectrometry systems*

ISO 11929-1:2000, *Determination of the detection limit and decision threshold for ionizing radiation measurements – Part 1: Fundamentals and application to counting measurements without the influence of sample treatment*

ISO 11929-4:2001, *Determination of the detection limit and decision threshold for ionizing radiation measurements – Part 4: Fundamentals and application to measurements by use of linear-scale analogue ratemeters, without the influence of sample treatment*

2.2 Other International references

ICRP 38:1983, *Radionuclide Transformations: Energy and Intensity of Emissions*. Annals of the ICRP 11-13

ICRP 60:1990, *Recommendations of the International Commission on Radiological Protection*. Annals of the ICRP 21 No. 1-3, 1991

ICRP 61:1991, *Annual Limits on Intake of Radionuclides by Workers Based on the 1990 – Recommendations*. Annals of the ICRP 21 No. 4.

ICRP 68:1994, *Dose Coefficients for Intakes of Radionuclides by Workers: A Replacement of ICRP 61*. Annals of the ICRP 24 (4).

ICRP 75, *General Principles for the Radiation Protection of Workers*

3 Terms and definitions

General terminology concerning detection and measurement of ionizing radiation is given in IEC 60050(393), IEC 60050(394), and in IEC 61276. For the purposes of this document, the definitions from the recommendations of ICRP 68 and ICRP 75 are applicable, as well as the following definitions.

3.1

conventionally true value of activity

best estimate of activity

value and its uncertainty determined from a primary or secondary standard or by means of a reference instrument which has been calibrated against primary or secondary radioactive sources

3.2**indicated (measured) activity**

activity indicated by the measuring assembly under test

3.3**coefficient of variation**

ratio V of the standard deviation s to the arithmetic mean of set of n measurements x_i given by the following formula

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

3.4**calibration**

process of determination of the numerical relationship between the observed indication and the value of the quantity being measured

3.5**reference radiation response (sensitivity)**

R_{ref}

response of the assembly under standard test conditions (Table 1) to the reference activity expressed as

$$R_{\text{ref}} = \frac{I_{\text{rp}} - I_{\text{b}}}{A_{\text{t}}}$$

where

I_{rp} is the indication due to the conventionally true activity of the reference source and to the background;

I_{b} is the indication due to the background alone;

A_{t} is the conventionally true activity of the reference source.

3.6**minimum detectable activity**

activity determined in accordance with ISO 11929-1

3.7**dynamic range**

quotient of the signal from the maximum measurable indication of a quantity to the signal from the minimum detectable value of that quantity

3.8**error of indication**

difference between the indicated activity A_i and the conventionally true activity at the point of measurement A_c

$$\Delta A = A_i - A_c$$

3.9**relative error of indication**

quotient, expressed as a percentage, of the error of indication by the conventionally true value

3.10

relative intrinsic error

relative error of indication of a piece of equipment or an assembly with respect to a quantity when subjected to a specified reference quantity under specified reference conditions expressed as

$$F = \frac{A_i - A_t}{A_t}$$

where

A_i is the indicated value of a quantity;

A_t is the conventionally true value of the quantity at the point of measurement C *Text deleted* C.

3.11

effective range of measurement

range of values of the quantity to be measured over which the performance of a piece of equipment or assembly meets the requirements of its specifications C

3.12

measurement time

time delay between the initiation of the measurement and the attainment of the final reading

3.13

C relative C energy resolution

C *Text deleted* C

The relative energy resolution C ε_R C is given by

$$\text{C } \varepsilon_R = \frac{\text{full width in terms of energy (or channel number)}}{\text{the energy (or channel number) of the centroid of the energy of interest}} \text{C}$$

C Where the full width is measured between the two points on the spectrum situated on either side of the centroid due to the energy of interest where the count rate in the energy channel is half that of the peak maximum. C

NOTE The full width may not be symmetric in relation to the centroid.

3.14

qualification test

test performed in order to verify that the requirements of a specification are fulfilled

NOTE Qualification tests are subdivided into type tests and routine tests.

3.15

type testing

conformity testing on the basis of one or more specimens of a product representative of the production

[IEV 394-20-28]

3.16

routine test

test to which an individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[IEV 394-20-08]

3.17**acceptance test**

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

[IEV 394-20-09]

3.18**units**

units of the International System (SI)¹ are used. The definition of radiation quantities and dosimetric terms are given in IEC 60050(393) and IEC 60050(394). The corresponding non-SI units are indicated in brackets

3.19**activity**

the SI unit of radioactivity of any material is the Becquerel (symbol Bq)

1 Bq = 1 nuclear transition (decay) in a second

= 1 decay s⁻¹

The quantity has the unit s⁻¹

3.20**Non-SI units**

The following units are also used for convenience:

For energy: electron volt (eV)

1 eV = 1,602 × 10⁻¹⁹ J

For time: year (y), day (d), hour, (h), minute (min)

4 Classification**4.1 General classification**

Dependent on the  radionuclides  and on the range of energy to be detected in vivo, monitors can be conveniently classified taking account of two considerations:

- the range of energy;
- the specificity of the measurement.

Besides, whole body counters or other types of in vivo monitoring systems can be classified into four types depending on the following:

- problem and task to be solved;
- the number of operational staff;
- the number of people to be monitored;
- the type of nuclear accident (for post-accident monitoring);
- the local environment;
- the method used to transport the system.

NOTE Since in vivo counters may include gamma-spectrometers, their characteristics may correspond to one of the groups of Tables 4 and 5 of IEC 61276.

¹

Bureau international des poids et mesures: Le Système international d'unités (SI), 7e édition, 1998

4.2 Energy range classification

4.2.1 Low energy in vivo monitoring (range from 10 keV to 200 keV)

These in vivo counters are used for the detection of low-energy emitters (essentially actinides such as Pu, Am, U and electron capture nuclides). Because of their minimal translocation, these radionuclides are normally located in the lung, and measurements are made preferentially in this organ. However, measurements in other organs can also be considered.

4.2.2 High energy in vivo monitoring (range from 100 keV to 3 MeV)

These in vivo counters are used for the detection of high-energy emitters including activation products and fission product measurements. Because of their rapid translocation, the measurements are generally made on the whole body. However, measurements in other organs can also be considered.

4.3 Specificity of the measurement

This is dependent on the number of operational staff, the number of people to be monitored, the type of nuclear accident (for post-accident monitoring), the local environment and the method of transporting the monitoring equipment to any site.

4.3.1 Type 1 – Nuclide specific, spatially specific with very low background

These in vivo counters are precise low-level radiological monitoring equipment for the measurement of radioactivity as accurately and precisely as possible and are generally installed in atomic energy research institutions, atomic power plants, emergency treatment centres laboratories, universities and hospitals for research purposes.

The detector assemblies and driving mechanisms to move the detectors are mounted in a shielded room where special attention is paid to the materials lining the walls and to the air entering the room (radon).

Data processing and analysis and display and data storage equipment complete the whole monitoring equipment.

4.3.2 Type 2 – Nuclide specific, spatially specific with low background

These in vivo counters are used for the estimation of internal dose of individuals and are normally intended for atomic energy research institutions, atomic power plants, emergency treatment centres, etc.

The structure of this type of in vivo counter is suited to the more rapid monitoring of many subjects; a shadow shield structure (open structure covering only the detectors and their accessories), simpler than the type 1 construction, would meet this requirement.

4.3.3 Type 3 – Nuclide specific

These in vivo counters are general screening counters for radiation workers and for the mass screening of the general public after nuclear accidents. This latter screening may be an initial measurement or a subsequent measurement to determine any changes in condition.

These units are relatively easy to transfer from one place to another.

4.3.4 Type 4 – Non-nuclide and non-spatial specific

These in vivo counters perform a similar function to the type 3 and are very similar in design except that the detectors may be quite large.

NOTE Because of the difficulty of measurement and the high background dependency, measurements in the low-energy range need low background equipment. Consequently, the type 3 and type 4 equipment is not used for this range of energy.

5 General

5.1 General description of the instrument

5.1.1 General

Measurements shall be easy to make and shall be made as quickly as possible relevant to the sensitivity required so that a large number of workers or a general population can be dealt with efficiency. Facilities shall be available to introduce the results into a database.

The instruments shall be calibrated with the help of phantoms simulating the human body or where applicable separate human organs.

The instrument for measurement of the content of radionuclides in the human body may consist of the following main components:

- monitoring equipment for the detection of radioactivity including detection assembly and measurement assembly;
- auxiliary equipment.

The monitoring equipment for the detection of radionuclides contains the following parts which may or may not form a single mechanical assembly:

- detection assembly;
- measurement assembly.

5.1.2 Detection assembly

The detection assembly may consist of the following units:

- detector (scintillation counters or semi-conductor detectors, in the latter case including cryostat);
- preamplifier(s);
- additional detector(s) for the determination of ambient background radiation and compensation of the measurement against ambient background radiation;
- stable power supply for the detectors;
- collimator(s);
- shielding (iron, lead, etc.);
- chamber, armchair, chair, couch, cell, etc. (depending on the measurement geometry).

5.1.3 Measurement assembly

The measurement assembly may consist of some or all of the following units:

- measuring assembly for primary detector(s);

- measuring assembly for ambient background monitoring compensation circuit;
- systems for the entry and treatment of anatomical information (weight, height, etc.);
- measurement unit, or spectrometer;
- data processing unit;
- stable power supply.

5.1.4 Auxiliary equipment

The auxiliary equipment may consist of the following units:

- drives for auxiliary recording and information storage;
- mass (weight) determination equipment;
- phantoms;
- source(s) for producing a high-quality check spectrum.

5.1.5 Ease of operation

The design of the instrument and equipment shall be such that the placing of the subject into the correct measuring position and movement from this position is easy.

5.1.6 Ease of decontamination

The detector(s) and other parts of the instrument and equipment shall be designed so as to minimize the possibility of contamination and be both easy to de-contaminate and dismantle.

This is not applicable to situations where the risks of contamination are excluded.

5.1.7 Size of subject

The equipment shall be designed to monitor all persons between 145 cm and 200 cm in height and having a maximum anterior-posterior dimension of 40 cm.

Where the equipment is designed to monitor children, the dimensional limits of the children for whom the particular equipment is designed shall be stated by the manufacturer.

5.2 Measurement method

To obtain the maximum performance, low background shielding or collimation of the detectors shall be used in combination with the optimum position of the subject dependent on whether the equipment is designed for the subject to be standing, sitting, or lying.

5.3 Energy range

The energy range should be as defined in 4.2.

Where the equipment is to measure specific radionuclides, instruments shall be set to measure the primary photon emission of the radionuclides of interest. It should be possible, either manually or automatically, to change the discriminator levels and channel widths so that other radionuclides with emissions within the specified energy range can be measured.

Indication of the threshold levels set in terms of energy, the primary photon energy being detected or the nuclides being measured shall be given.

5.4 Background

Indicated background radiation is due to

- ambient background radiation;
- intrusive radioactivity in the components of the instrument or equipment;
- contamination of the detector and/or chair, etc.;
- detector assembly noise;
- naturally occurring internal activity (potassium-40).

Since some instruments may be in continuous use, periodic checks should be made for any change in background conditions. Background checks may be carried out automatically. Where changes in the settings are made (for alternative nuclides), indication shall be made of the necessity of changing the background compensation where this is not automatic or of the necessity of accumulating background information where background compensation is not automatic. It shall not be possible to alter such settings during the measurement of contamination in a person.

5.5 Measurement range

The range of measurement shall not be less than three decades. The instrument shall operate within the requirements of this standard over the whole indicated measuring range.

5.6 Minimum detectable activity

Reference should be made to ISO 11929-1 for the determination of the minimum detectable count-rate.

For any particular measurement the minimum detectable activity can be determined from the relationship

$$\frac{LLD}{\varepsilon}$$

where ε is the efficiency of detection for the measurement of a particular radionuclide in a specified organ, normally expressed in count-rate per unit of activity (Bq);

LLD is the lower limit of decision threshold in terms of count rate and equal to

$$\frac{1}{2t_0} k_{1-\alpha}^2 \left[1 + \sqrt{1 + \frac{4R_b t_0}{k_{1-\alpha}^2} \left(1 + \frac{t_0}{t_b} \right)} \right]$$

where

- R_b is the background count rate;
- t_0 is the measuring time;
- t_b is the background measuring time;
- $k_{1-\alpha}$ are the quantiles of the standard normal distribution.

For the purposes of meeting the requirements of this standard, $k_{1-\alpha}$ shall take the value 2,326 i.e. there will be 1 % risk of activity indicated when in fact there is no activity present.

6 Characteristics of equipment for low-energy emitter measurement

6.1 Energy range (10 keV to 200 keV)

The equipment shall have the capability of resolving specific gamma or X-rays of energy between at least 10 keV and 200 keV.

6.2 Minimum detectable activity

The minimum detectable activity shall be determined for each type of instrument for specified background conditions and monitoring time for each of the radionuclides of interest (see 5.6).

6.3 Ranges of measurement of activity

As a minimum, the equipment shall be capable of measuring in the body or organ of interest the following activities for either Am-241 or U-235 where the background in the vicinity of the equipment is as given under the reference condition given in Table 1. These activities are specified in becquerels and relate to a 1 % confidence interval ($k_{1-\alpha} = 2,326$ as given in ISO 11929-1 for the limit of detection).

		Am-241	U-235
Type 1	In vivo counters	25	25
Type 2	In vivo counters	45	40

6.4 Energy resolution

The energy resolution of scintillation detector-based instruments shall not exceed an FWHM (full width half maximum) of 25 keV for the 59,54 keV gamma line of Americium-241 decay and shall be stated by the manufacturer.

The energy resolution of Germanium semi-conductor detector-based instrument should not exceed an FWHM of 1,5 keV for the 59,54 keV gamma line of Americium-241 and shall not exceed 2 keV for the 122,1 keV gamma line of Cobalt-57 and shall be stated by the manufacturer.

NOTE These resolutions are obtained with spectrometric sources (see 5.1.4) in free space, but spectra obtained in normal operation will be distorted because of self-absorption and scattering of quanta in tissue. The degree of distortion depends on the location of the radionuclide in the body.

6.5 Integral non-linearity

The permissible limit of the integral non-linearity under reference conditions for instruments with scintillation detectors shall not exceed

– $\pm 0,5 \%$ for type 1 and type 2 in vivo counters.

The permissible limit of integral non-linearity under reference conditions for instruments with Germanium semi-conductor detectors shall not exceed

- $\pm 0,1$ % for type 1 in vivo counters;
- $\pm 0,2$ % for type 2 in vivo counters.

6.6 Natural background level

The measured background count-rate for the stated energy regions shall be defined for a natural external background. The level of the natural background shall be specified.

The manufacturer shall state the background count-rate obtained from the naturally occurring background under normal operating conditions (with a non-radioactive phantom present). For nuclide specific counters, this shall relate to a number of specific energy regions. The manufacturer shall state the background dose equivalent rate at which the measurements were made. In the case of fixed installations, this information shall relate to the background at the installation.

6.7 Reference radiation response

The response of the equipment

- shall be determined for a particular nuclide dependent on the organ of interest
- or
- shall be as defined by ISO for the purposes of lung counting²
- or
- shall be agreed between the purchaser and the manufacturer, and the manufacturer shall specify the phantom used.

Where the counting is specific to particular organs or parts of the body the phantoms used shall be by agreement between the purchaser and manufacturer.

The manufacturer shall specify the method used to determine the reference radiation response.

For the lungs, the response to the 59,54 keV gamma line of Americium-241 shall be determined by the use of a uniformly contaminated lung phantom within an inactive whole body phantom.

7 Characteristics of equipment for high-energy emitter measurements 100 keV to 3 MeV

7.1 Minimum detection activity

The minimum detection capability shall be determined for each type of instrument for specified background conditions and monitoring time for each of the radionuclides of interest (see 5.6).

² At the time of publication of this document, no ISO document exists.