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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Radiation protection instrumentation – Spectroscopy-based alarming Personal Radiation Detectors (SPRD) for the detection of illicit trafficking of radioactive material

Instrumentation pour la radioprotection – Détecteurs individuels spectroscopiques d'alarme aux rayonnements (SPRD) pour la détection du trafic illicite des matières radioactives

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

FDIS	Report on voting
45B/751/FDIS	45B/758/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

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RADIATION PROTECTION INSTRUMENTATION – SPECTROSCOPY-BASED ALARMING PERSONAL RADIATION DETECTORS (SPRD) FOR THE DETECTION OF ILLICIT TRAFFICKING OF RADIOACTIVE MATERIAL

1 Scope and object

This International Standard applies to Spectroscopy-based alarming Personal Radiation Detectors (SPRD) which represent a new instrument category between alarming Personal Radiation Devices (PRD) and Radionuclide Identification Devices (RID). SPRDs are advanced PRDs that can be worn on a belt or in a pocket to alert the wearer of the presence of a radiation source. They are not intended for accurate measurement of personal or ambient dose equivalent (rate). In addition to the features of conventional PRDs, SPRDs provide rapid simultaneous search and identification capability to locate and identify radiation sources. They can discriminate innocent alarms such as Naturally Occurring Radioactive Materials (NORM) or medical radionuclides against industrial sources or Special Nuclear Material (SNM). Because of their limited sensitivity, SPRDs cannot replace RIDs. For first responders, SPRDs can be particularly useful for immediate response measures.

This standard does not apply to the performance of radiation protection instrumentation which is covered in IEC 61526 and IEC 62401.

The object of this standard is to establish performance requirements, provide examples of acceptable test methods and to specify general characteristics, general test conditions, radiological, environmental, mechanical and electromagnetic characteristics that are used to determine if an instrument meets the requirements of this standard. The results of tests performed provide information to end-users and manufacturers on instrument capability for reliable detection, localization and identification of radiation sources.

Obtaining operating performance that meets or exceeds the specifications as stated in this standard depends upon properly establishing appropriate operating parameters, maintaining calibration, implementing a suitable maintenance program, auditing compliance with quality control requirements and providing proper training for operating personnel.

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 60050-393:2003, *International Electrotechnical Vocabulary (IEV) – Part 393: Nuclear instrumentation – Physical phenomena and basic concepts*

IEC 60050-394:2007, *International Electrotechnical Vocabulary (IEV) – Part 394: Nuclear instrumentation – Instruments, systems, equipment and detectors*

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 performance requirements*

IEC 62755, *Radiation protection instrumentation – Data format for radiation instruments used in the detection of illicit trafficking of radioactive materials*

ISO 4037-3, *X and gamma reference radiation 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*

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

ICRU Report 39:1985, *Determination of Dose Equivalents Resulting from External Radiation Sources, International Commission on Radiation Units and measures*

ICRU Report 47:1992, *Measurement of Dose Equivalents from External Photon and Electron Radiations, International Commission on Radiation Units and measures*

3 Terms, definitions, abbreviations, 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 60050-393 and IEC 60050-394 apply.

3.1.1
acceptable or correct identification
when an instrument correctly identifies only the radio nuclides present

3.1.2
accuracy of measurement
closeness of the agreement between the result of a measurement and the conventionally true value of the measurand

Note 1 to entry: “Accuracy” is a quantitative concept.

Note 2 to entry: The term precision should not be used for “accuracy”.

[SOURCE: IEC 60050-394:2007, 394-40-35]

3.1.3
alarm
an audible, visual, or other signal activated when the instrument reading exceeds a preset value or falls outside of a preset range

3.1.4
alarm criteria
condition that causes an instrument to alarm

3.1.5
ambient dose equivalent H*(10)
dose equivalent at a point in a radiation field, 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 (see ICRU Report 39 and 47)

Note 1 to entry: 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 characterise these derived radiation fields. In the expanded field, the fluence and its angular and energy distribution have the same values 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 2 to entry: The ICRU sphere (see ICRU Report 33) is a 30 cm diameter, tissue-equivalent sphere with a density of 1 g·cm^{-3} and a mass composition of tissue equivalent material (see IEC 60050-393, 393-14-78).

Note 3 to entry: The recommended depth d, for environmental monitoring in terms of H*(d) is 10 mm, and H*(d) may then be written as H*(10).

Note 4 to entry: An instrument that has an isotropic response and is calibrated in terms of H*(d) will measure H*(d) in radiation fields that are uniform over the dimensions of the instrument.

Note 5 to entry: The definition of H*(d) requires the design of the instrument to take account of backscatter.

[SOURCE: IEC 60050-393:2003, 393-14-95]

3.1.6

ambient dose equivalent rate $\dot{H}$*(10)
the quotient of the ambient dose equivalent at the recommended depth for environmental monitoring of 10 mm dH*(10) by dt, where dH*(10) is the increment of ambient dose equivalent in the time interval dt (see 3.4)

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

3.1.7
background radiation level
radiation field in which the instrument is intended to operate, including background produced by naturally occurring radioactive material

3.1.8
confidence indication
an indication provided by the instrument to assess the reliability assigned to the validity of the identification. For each identified radionuclide, the instrument indicates the likelihood of its correct identification.

3.1.9
coefficient of variation

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

$$COV = \frac{s}{\bar{x}} = \frac{1}{\bar{x}} \cdot \sqrt{\frac{1}{n-1} \cdot \sum_{1}^{n} \left(x_i - \bar{x}\right)^2}$$

[SOURCE: IEC 60050-394:2007, 394-40-14]

3.1.10
conventionally true value of a quantity
value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose

Note 1 to entry: "Conventionally true value of a quantity" is sometimes called assigned value, best estimate of the value, conventional value or reference value.

Note 2 to entry: A conventionally true value is, in general, regarded as sufficiently close to the true value for the difference to be insignificant for the given purpose. For example, a value determined from a primary or secondary standard or by a reference instrument, may be taken as the conventionally true value.

[SOURCE: IEC 60050-394:2007, 394-40-10]

3.1.11
false alarm
alarm not caused by an increase in radiation level over background conditions

3.1.12
functionality test
procedure to measure potential changes in the instrument response, such as drift in energy calibration or sensitivity

3.1.13
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.

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

3.1.14
innocent alarm
an alarm caused by an increase in radiation resulting from non-threat radioactive material such as NORM (e.g. fertilizer, ceramic tiles) or medical radionuclides

3.1.15
manufacturer
includes the designer of the equipment

3.1.16
precision
the degree to which repeated measurements under unchanged conditions show the same result (also called reproducibility or repeatability)

3.1.17
radioactive material
material containing one or more constituents exhibiting radioactivity

Note 1 to entry: For the purpose of this standard, radioactive material includes special nuclear material.

[SOURCE: IEC 60050-393:2003, 393-12-46]

3.1.18
reference point of an instrument
mark on the equipment at which the instrument is positioned for the purpose of calibration

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

Note 2 to entry: The reference point for calibration is also used as reference point for testing.

[SOURCE: IEC 60050-394:2007, 394-40-15]

3.1.19
reference source
radioactive secondary standard source for use in calibration of the measuring instrument

Note 1 to entry: In this standard, reference sources for calibration are used for testing.

[SOURCE: IEC 60050-394:2007, 394-40-19]

3.1.20
safety alarm
an audible and visual signal for detection of high radiation levels, which requires immediate radiation safety measures

3.1.21
source indication alarm
an audible and/or visual signal to indicate the presence of a radiation source

3.1.22
standard test conditions
the range of values of a set of influence quantities under which a test, calibration or measurement of response is carried out

3.1.23
performance test
environmental, mechanical or electrical test taken from IEC 62706

3.1.24
type test
conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-394:2007, 394-40-02]

3.2 Abbreviations

AA	battery size – Mignon / LR6
CL	Confidence Level
COV	Coefficient of Variation
CZT	Cadmium Zinc Telluride
DU	Depleted Uranium (see Table D.1)
FAR	False Alarm Rate
HDPE	High Density Polyethylene
HEU	Highly Enriched Uranium (see Table D.1)
ICRU	International Commission on Radiation Units and Measurements
LEU	Low Enriched Uranium (see Table D.1)
PC	Personal Computer
PMMA	Polymethylmethacrylate
PRD	(alarming) Personal Radiation Detector (Device)
NORM	Naturally Occurring Radioactive Material
RGPu	Reactor Grade Plutonium
RID	Radionuclide Identification Device
SNM	Special Nuclear Material
SPRD	Spectroscopy based Personal Radiation Detector
WGPu	Weapons Grade Plutonium

3.3 Quantities and units

In the present standard, units of the International System (SI) are used[1]. The definitions of radiation quantities are given in IEC 60050-393 and IEC 60050-394. Nevertheless, the following units may also be used:

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

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

3.4 Simplification of terms

Within this standard the following simplification of terms is used to accelerate reading and to facilitate understanding of the text:

"dose rate" replaces **"ambient dose equivalent rate $\dot{H}^*(10)$"**

SPRDs are not intended for accurate measurement of the personal dose equivalent (rate) $H_p(10)$, therefore no reference to such quantities is needed and the term "dose (rate)" can unambiguously replace the term "ambient dose equivalent (rate)" throughout the standard.

4 General test procedure

4.1 Nature of tests

The required standard test conditions for influence quantities, such as temperature and pressure, as well as those for other quantities that may influence the performance of instruments, are given in Table A.1. Acceptable testing ranges for these quantities shall be met, except where the effect of the condition or quantity itself is being tested.

The tests in this standard are to be considered as type tests (see Table B.1) unless otherwise stated. The user may employ certain parts of the standard as acceptance tests. The required specifications are evaluated by the tests given in the appropriate Clauses. All tests in this standard shall be performed using the same instrument setup with any accessories included with the instruments. Where no test is specified, it is understood to mean that the characteristic can be verified by observation or consultation of the manufacturer's specifications.

4.2 Reference conditions and standard test conditions

4.2.1 General

Ideally, measurements or calibrations should be carried out under reference conditions. Since it is not always possible to maintain these conditions, a small interval around the reference values may be used (these are the standard test conditions).

Reference and standard test conditions are given in Table A.1. Reference conditions are those conditions to which the performances of the instrument are valid and standard test conditions indicate the necessary tolerances in practical testing.

Except where otherwise specified, the tests in this standard shall be performed under the standard test conditions given in the third column of Table A.1.

4.2.2 Tests performed under standard test conditions

Tests which are performed under standard test conditions are listed in Table B.1 which indicates, for each characteristic under test, the requirements according to the Clause where the corresponding test method is described. For these tests, the value of temperature, pressure and relative humidity at the time of the test shall be stated.

4.2.3 Tests performed with variation of influence quantities

For tests intended to determine the effects of variations in the influence quantities given in Table 1, all other influence quantities shall be maintained within the limits for the standard test conditions given in Table A.1 unless otherwise specified in the test procedure concerned.

4.3 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuations of the indication arising from the random nature of radiation alone is a significant fraction of the

variation of the indication permitted in the test, then sufficient readings shall be taken to ensure that the mean value of such readings may be estimated with sufficient precision to determine whether the requirements for the characteristic under test are met. The interval between such readings shall be sufficient to ensure that the readings are statistically independent.

4.4 Radiation field requirements

4.4.1 Instrument orientation

When performing radiation tests as described in this standard, the reference point of the instrument shall be placed at the point of measurement, and the instrument shall be oriented with respect to the direction of the radiation source as indicated by the manufacturer.

4.4.2 Traceability

Radiation fields used to perform the tests of this standard shall be traceable to national or international standards. This can be achieved either by measurement of the applied dose rate using instruments showing a valid traceable calibration or alternatively by using certified reference sources traceable to national or international standards, under defined measurement geometry.

If the dose rate is calculated from the source activity, corrections for the self-shielding of the source should be considered.

If the source has a long decay chain all progeny needs to be accounted for in dose rate calculation from the source activity. If necessary, the source age needs to be considered by application of decay corrections.

4.4.3 Field homogeneity

If not otherwise stated, the closest distance from the source to the reference point of the instrument shall be at least 50 cm to ensure that the radiation field is sufficiently homogenous. For neutron sources, a distance of 25 cm is acceptable. For testing of identification capabilities (see 6.10, 6.11, 6.12, 6.13, and 6.14) and for functionality tests (see 4.6) smaller distances are acceptable.

4.4.4 Neutron measurement

For testing of the neutron measurement capabilities, neutron scatter, and moderation by the human body have to be considered. Neutron tests should be made in a low scatter irradiation facility (see ISO 8529-1:2001) or with the instrument placed in an area where the open space around the instrument and source is at least 2 m on all sides. The instrument shall be mounted centred on the front side of a standard 30 cm × 30 cm × 15 cm ICRU phantom made from PMMA or similar plastic (see ICRU reports 39 and 47).

NOTE Functionality tests (see 4.6.3) are only intended to monitor a change but not an absolute response. Therefore the requirements in this subclause do not apply to tests in Clauses 7, 8, and 9.

4.5 Radionuclide identification

4.5.1 Identification results

Most of the radionuclides likely to be encountered at borders having photon energies between 60 keV and 1,5 MeV should be identified. The radionuclides of greatest interest and those most likely to be encountered are listed below. Radionuclides shall be identified by indicating the individual radionuclide and the relevant category, i.e. nuclear, medical, industrial, or NORM. For special nuclear material it is sufficient to display the element and category (see Table D.1). When identifying radionuclides, the results are acceptable when the SPRD identifies the radionuclide(s) of interest, or the radionuclide(s) and expected progeny and radionuclides present in the background (e.g. ^{40}K, ^{232}Th decay chain, ^{238}U decay chain). It is