BS EN 62618:2016

BSI Standards Publication

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

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National foreword

This British Standard is the UK implementation of EN 62618:2016. It is identical to IEC 62618:2013.

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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English Version

Radiation protection instrumentation - Spectroscopy-based alarming Personal Radiation Detectors (SPRD) for the detection of illicit trafficking of radioactive material (IEC 62618:2013)

Instrumentation pour la radioprotection - Détecteurs individuels spectroscopiques d'alarme aux rayonnements (SPRD) pour la détection du trafic illicite des matières radioactives
(IEC 62618:2013)

Strahlenschutz-Messgeräte - Spektroskopie-basierte alarmgebende persönliche Strahlungsdetektoren für den Nachweis von unerlaubt transportiertem radioaktivem Material
(IEC 62618:2013)

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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 62618:2016) consists of the text of IEC 62618:2013 prepared by SC 45B "Radiation protection instrumentation" of IEC/TC 45 "Nuclear instrumentation".

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2017-09-05
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2019-09-05

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The text of the International Standard IEC 62618:2013 was approved by CENELEC as a European Standard without any modification.

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 60050-393	2003	International Electrotechnical Vocabulary - Part 393: Nuclear instrumentation - Physical phenomena and basic concepts	-	-
IEC 60050-394	2007	International Electrotechnical Vocabulary - Part 394: Nuclear instrumentation - Instruments, systems, equipment and detectors	-	-
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	-	-
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		

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

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International Standard IEC 62618 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

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

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

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

not acceptable if the instrument identifies non-present radionuclides or only the progeny of the radionuclide(s) of interest (see Annex E for additional information).

4.5.2 Radionuclide categorization

The radionuclides of great interest (SNM) or those most likely to be encountered (medical industrial and NORM) can be divided in four different categories. This is an informative list and should not be considered as all-inclusive.

Special nuclear materials:	Uranium (used to indicate ^{233}U, ^{235}U), ^{237}Np, Plutonium (used to indicate ^{239}Pu, ^{241}Pu).
Medical radionuclides:	^{18}F, ^{67}Ga, ^{51}Cr, ^{89}Sr, ^{99}Mo, ^{99m}Tc, ^{103}Pd, ^{111}In, Iodine (^{123}I, ^{131}I), ^{153}Sm, ^{201}Tl, ^{133}Xe.
Industrial radionuclides:	^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{192}Ir, ^{226}Ra, ^{152}Eu, ^{22}Na, ^{241}Am.
NORM:	^{40}K, ^{226}Ra and progeny (used also to indicate natural U in secular equilibrium), ^{232}Th and progeny.

4.6 Functionality tests

4.6.1 General

Functionality tests are performed before, during or after performance testing to assess potential changes in the instruments response, such as drift in energy calibration or sensitivity. Instead of being used as an independent test, they are always combined with an environmental, mechanical, or electromagnetic test from IEC 62706, hereinafter referred to as performance tests.

Four parameters are verified by the functionality test:

– photon response;
– photon energy calibration;
– neutron response (if applicable);
– spurious indications (alarms or identifications).

4.6.2 Photon response

To cover the whole photon energy range of the instrument (see 6.6 and 6.7), an ^{241}Am source is combined with a ^{60}Co source. Each source shall increase the dose rate at the reference point of the instrument by 2 $\mu Sv \cdot h^{-1} \pm 50$ %.

NOTE The value of 2 $\mu Sv \cdot h^{-1}$ corresponds to 4 times the value used for testing the source indication alarm (see 6.2).

4.6.3 Neutron response

Simultaneously, the response to neutrons (if applicable) is measured by using an unmoderated ^{252}Cf source (see Clause 6.7). This source shall provide an increase in the neutron indication, corresponding to 20 $n \cdot s^{-1} \cdot cm^{-2} \pm 50$ %.

NOTE Functionality tests are only intended to monitor a change but not an absolute response. Therefore the requirements in 4.4.4 do not apply to tests employed in Clause 7, 8, and 9.

4.6.4 Field stability and reproducibility

The photon check field is combined with the neutron check field (if applicable). During environmental testing the source-detector geometry should not be changed to maintain a stable reference field. If a change is necessary, suitable mechanical measures (such as precision fixture for sources and instrument) shall be used to ensure proper reestablishment of the geometry. In such case, reproducibility of the set-up shall be verified by repeated set-up of the check field and quantified by assessing the variation between these repetitions. The

coefficient of variation (COV) shall be less than 0,1 (10 % variation), when setting up the geometry for testing the instrument.

NOTE This level of COV may not be achievable for measurements at background levels.

4.6.5 Combination of functionality tests and performance tests

Before performance testing (e.g. environmental), the reference fields are set-up according to 4.6.2 and 4.6.3. A functionality test shall be carried out to maintain reference values for the instrument's response. After performance testing, the fields shall be re-established (if applicable) according to 4.6.4 and a functionality test shall be carried out to monitor changes in the instrument's response. If required by the test matrices (see 7.3, 8.3, and 9.3), additional functionality tests can be performed during performance testing.

4.6.6 Performance of functionality tests

Each functionality test should be performed in the following way: Record 10 independent photon dose rate readings. If the system is equipped with a neutron sensor, verify that the system indicates the presence of a neutron source and record 10 independent neutron count rate readings. Calculate the mean and standard deviation of the photon (neutron) count rate or dose rate readings. Collect three 3 min spectra and record the radionuclides identified. Determine the mean and standard deviation of the photopeak centroids (60 keV, 1 173 keV, 1 332 keV) from the 3 spectra. For each functionality test, this procedure will result in two parameters (see 4.6) quantifying the photon sensitivity and photon energy calibration. Each parameter consists of two components, a mean value and a corresponding standard uncertainty. For instruments with neutron capabilities, additionally a third parameter, the neutron sensitivity, will result. When the instrument is exposed to the different test conditions described in this standard these three parameters are calculated. The deviation in the instrument response between the measurements performed at the standard or reference test conditions and those performed at other conditions is calculated and used to determine the acceptance range.

The results are acceptable, if the deviation pertaining to the photon or neutron (if applicable) sensitivity does not exceed ±30 % and if the deviation pertaining to the peak centroid does not exceed ±3 % and the nuclide identification has not changed.

NOTE The standard deviation is calculated and recorded only to monitor data quality.

4.6.7 Spurious indications

In addition to the functionality tests, which assess drift in instrument response, another requirement denoted "regular operation behaviour" is applied by performance tests. That part of the test is performed without the presence of radiation sources. The test matrices (7.3, 8.3, and 9.3) indicate when the instrument shall show regular operation behaviour during testing. This requires that the FAR is not higher than defined in 6.1 and solely NORM radionuclides, which are present in the background, shall be identified. The display shall operate successfully and without spurious indications (e.g., alarms, false identifications, unexpected messages or displays, instrument shut down).

5 General requirements

5.1 General characteristics

Instruments addressed by this standard are used for the detection of photon and neutron radiation (neutron detection is optional) as well as for localization and identification of the source. These instruments are body worn and battery-powered. SPRDs have the typical characteristics of standard PRDs, with additional radionuclide identification capability. Although these instruments are not primarily designed to measure ambient dose equivalent rate $\dot{H}^*(10)$, their indication shall provide an approximate value that is sufficiently accurate to allow their use as a warning device, to prevent accidental exposure to high radiation fields.

5.2 Physical configuration

The instrument case design shall meet the requirements stated for IP code 54 (see IEC 60529 and IEC 62706). Controls and adjustments that may affect the operation of the instrument including setting of alarms shall be designed so that access to them is limited to authorized persons. Provisions shall be made to permit testing of visual and/or sound warning indicators without the use of radiation sources.

5.3 Basic information

5.3.1 Documentation supplied

The manufacturer shall provide instrument performance specifications and instructions for operation.

5.3.2 Radiation detector

The manufacturer shall provide information describing the radiation detector types used and their associated dimensions and location within the instrument (e.g., NaI(Tl), CZT, ^{3}He). For gas-filled counter tubes the internal pressure shall be stated by the manufacturer.

5.3.3 Range of measurement – photons

The effective photon energy response range shall be stated by the manufacturer and shall include the range from 60 keV (^{241}Am) to 1,33 MeV (^{60}Co). The manufacturer shall also state the measurement range for dose rate, which shall be at least from 1 $\mu Sv \cdot h^{-1}$ to 100 $\mu Sv \cdot h^{-1}$. The indication (display) range for dose rate, shall be at least from 0,1 $\mu Sv \cdot h^{-1}$ to 100 $\mu Sv \cdot h^{-1}$.

Typically, the indication (display) range is wider than the measurement range. The requirements for accuracy have to be fulfilled within the measurement range. Indications outside the measurement range are informative only (e.g. to indicate the background level) and cannot be used like real measurement results.

5.3.4 Range of measurement – neutrons

The manufacturer shall state the range of neutron energy and count rate that the instrument can measure (if applicable).

5.3.5 Range for radionuclide identification

The manufacturer shall state the dose or count rate range (with reference to ^{137}Cs) for identification, which shall be at least from 1 $\mu Sv \cdot h^{-1}$ to 100 $\mu Sv \cdot h^{-1}$.

5.3.6 Warm-up time

The manufacturer shall state the time required for the instrument to become fully operational from the off and standby position, which shall be less than 10 min. Warm-up time includes calibration, stabilisation and background measurement. An indication shall be provided to the user when the instrument is not fully operational.

5.3.7 Batteries and battery lifetime

If non-rechargeable batteries are used, they shall be widely available, not unique to the instrument, and be field replaceable with no special tools (e.g., AA). When rechargeable batteries are used, battery chargers shall meet appropriate electrical standards.

The instrument shall be equipped with an indicator of battery condition. The low-battery indication shall be displayed before the minimum voltage for proper operation is reached.

The manufacturer shall state the continuous operating time using the recommended batteries under standard conditions (functional and environmental) which shall be at least 100 h under non-alarm conditions for non-rechargeable batteries, 16 h for rechargeable batteries and greater than 30 min under alarm conditions for either type of batteries.

5.3.8 Explosive atmospheres

The manufacturer shall state whether the instrument is certified for use in explosive atmospheres and its category. Proof of certification shall be provided when claimed.

5.4 Mechanical characteristics

5.4.1 Size

The dimensions of the instrument shall be specified by the manufacturer but should not exceed 200 mm × 100 mm × 50 mm.

5.4.2 Mass

The mass of the complete instrument including batteries and holders shall be specified by the manufacturer and should not exceed 400 g.

5.4.3 Case construction

The instrument case should be smooth, rigid, and resistant to mechanical shock, dust-resistant, water-resistant and easy to clean/decontaminate. Means shall be provided to securely affix the instrument to the user (for example, a clip or ring), with attention given to the necessary orientation of the detector, alarm type and display.

5.4.4 Reference point marking

The instrument shall be clearly marked to indicate the position of the reference point for calibration and test purposes.

5.4.5 Switches

Switches or other controls shall be adequately protected to prevent accidental or unauthorized operation.

5.5 Data output

The instrument shall have the ability to transfer data to another device such as a personal computer. As a minimum each data output file shall contain:

– date and time of the measurement;
– dose rate indication;
– neutron count rate indication (if applicable);
– alarm type (gamma and/or neutron if applicable, personal protection);
– energy calibration;
– source categorization;
– radionuclides identified;
– confidence level indication;
– photon spectra.

The output data file shall meet the requirements listed in IEC 62755. The manufacturer shall provide information as to how these data are transferred to an external device.

5.6 User interface

The following features are considered essential (shall) or desirable (should) for the proper usability of SPRDs.

a) The following features *shall* be provided:
   - simple to use for non-expert users and user-friendly controls for routine operation;
   - separate indication of the type of radiation detected (photon and/or neutron if applicable);
   - separate photon and neutron (if applicable) source indication alarms, with visual, acoustical and (optional) vibration indications (see 6.3 and 6.5);
   - photon and neutron (if applicable) personal protection safety alarms, with visual, acoustical and (optional) vibration indications (6.4 and 6.7);
   - adjustable threshold levels for both neutron (if applicable) and photon alarms using a protected method of setting the alarm thresholds e.g., via external PC;
   - radionuclide identification and categorization by indicating the individual radionuclide and the relevant category, i.e., nuclear, medical, industrial and NORM as well as the confidence level (see 3.1.8);
   - audible and/or visual indication that corresponds to the magnitude of the radiation field (for example, increasing frequency or pitch of beep tone with increasing radiation signal);
   - readable display in all lighting conditions including darkness;
   - protection of the settings for all operational parameters;
   - diagnostic capabilities;
   - indication of battery status;
   - capability to store results and to download this data to a PC.

b) The following features *should* be provided:
   - silent alarms for covert operation such as vibration and/or earphone with user adjustable earphone volume to cope with the large variations in human hearing sensitivity and noise level (see 5.8).

5.7 Markings

5.7.1 Properties and conditions

All external instrument controls, displays and adjustments shall be identified as to their function. Internal controls needed for operation shall be identified through markings and referenced/explained in technical manuals. External markings shall be easily readable and permanently fixed under normal conditions of use. They should withstand decontamination procedures.

5.7.2 Exterior markings

The following markings shall appear on the exterior of the instrument:

- manufacturer and model number;
- unique serial number;
- location of the reference point;
- function designation for controls, switches, and adjustments that are not menu or software driven.

5.8 Alarms

5.8.1 Photon source indication alarm

A source indication alarm shall be provided when the measured dose rate or count rate is above the source indication alarm threshold. This alarm threshold shall be calculated by the instrument automatically from background measurements using techniques such as a user definable dose rate increment, count rate increment or a number of standard deviations relative to the measured mean background rate value. The alarm indication (visual, audible or (optional) vibrational) shall be independently selectable. The optional vibration alarm is intended for covert operations when an audible or visual alarm is not appropriate.

5.8.2 Photon safety alarm

A personal protection safety alarm shall be provided to alert the user when the measured dose rate is above a user-selected threshold level. A protection method of setting the safety alarm threshold in terms of dose rate, e.g., via external PC, shall be provided. The safety alarm shall be both visual and audible or alternatively (optional) vibrational and shall require an “acknowledge” or other similar control to silence the audible function. It shall not be possible to switch off all safety alarm indicators at the same time. The safety alarm shall be different or distinguishable from the source indication alarm. The personal protection safety alarm shall be functional over the stated energy range of the instrument.

5.8.3 Neutron source indication alarm

If neutron measurement capability is claimed by the manufacturer, an alarm indication shall be provided when the measured neutron field (count rate) is above the neutron source indication alarm threshold. The alarm indication (visual, audible and/or vibrational) shall be independently selectable.

5.8.4 Neutron safety alarm

If neutron measurement capability is claimed by the manufacturer, a personal protection safety alarm should be provided to alert the user when the measured neutron field (count rate) is above a user-selected threshold level. The following paragraph applies only if this function is provided:

A protection method of setting the safety alarm threshold, e.g., via external PC, shall be provided. If the alarm threshold is set in count-rate, the manufacturer shall provide information (table and/or function) to convert count-rate values into neutron dose rate. This calibration shall be done with the instrument placed on a ICRU phantom and by using an unmoderated ^{252}Cf source (see 4.4.4). The safety alarm shall be both visual and audible or alternatively (optional) vibrational and shall require an “acknowledge” or other similar control to silence the audible function. It shall not be possible to switch off all safety alarm indicators at the same time. The safety alarm shall be different or distinguishable from the neutron source indication alarm.

5.8.5 Audible indication rate for searching

To facilitate the location of sources, an audible signal shall be provided with a repetition rate and/or frequency that increases with the increase in the radiation level.

6 Radiation detection requirements

6.1 False alarm rate

6.1.1 Requirements

The False Alarm Rate (FAR) is the number of source indication alarms per unit time which are not caused by radiation sources but by other reasons such as statistical variations in the

measurement process, i.e., counting statistics, variations in natural background intensity (if not corrected for) or instrument susceptibility to electronic noise, microphonics or electromagnetic interference.

The personal protection safety alarm threshold is normally set much higher than the source indication alarm. Therefore the FAR is not of relevance for the personal protection safety alarm and it is only tested for the source indication alarm (see 5.8.1 and 5.8.3).

The FAR of the source indication alarm for both, photons or neutrons (if applicable) shall be not more than 1 per 60 min of continuous operation in a stable background environment (as stated in Table A.1).

The susceptibility of an instrument to statistical variations and hence its FAR is directly related to its sensitivity. The same threshold shall be used for testing the FAR and the detection sensitivity (source indication alarm test). The FAR test shall be performed before testing for detection sensitivity.

6.1.2 Method of test

The alarm threshold shall be the same as used for testing of the source indication alarm (see 6.2, 6.3, 6.5, and 6.6). Place the instrument in an area with a stable background radiation level according to the standard test conditions given in Table A.1.

The instrument shall not trigger more than 3 photon source indication false alarms and not more than 3 neutron source indication false alarms (if applicable) within the continuous search mode for a period of 8 h.

NOTE The maximum allowed number of false alarms has been calculated based on a 95 % upper confidence limit for a one-sided Poisson distribution.

6.2 Photon source indication alarm

6.2.1 Requirements

The instrument shall trigger a photon source indication alarm within 3 s, when exposed to an increase in the dose rate of 0,5 $\mu Sv \cdot h^{-1}$ at its reference point. This requirement shall be met for ^{241}Am, ^{137}Cs, and ^{60}Co sources.

6.2.2 Method of test

This test shall be performed after the false alarm test 6.1 by using the same source indication alarm threshold settings as for the false alarm test.

The dose rate at the reference point of the instrument should be raised by 0,5 $\mu Sv \cdot h^{-1} \pm 20$ % above the background radiation level (see Table A.1) within 1 s using a ^{137}Cs source.

After the step change, the photon source indication alarm shall be activated within 3 s. The alarm shall then be acknowledged and the process repeated nine additional times. There shall be a break of at least 90 s between the exposures to allow the instrument to adapt again to background radiation level. Results are acceptable when the alarm is activated at least 8 out of 10 exposures. If the alarm threshold is adjusted to meet the requirement of this test, the FAR test (6.1) shall be repeated.

The test shall be repeated with a ^{241}Am source, and again with a ^{60}Co source.

6.3 Photon indication – detection of gradually increasing radiation levels

6.3.1 Requirements

The source indication alarm shall be activated even by slowly increasing radiation levels that may be caused when the wearer is slowly approaching or is being approached by a radiation source. For testing purpose the fixed instrument is being approached by the radiation source.

6.3.2 Method of test

From the background radiation level (see Table A.1), increase the dose rate at the reference point of the instrument by slowly approaching a ^{137}Cs source, that produces a dose rate of 0,5 $\mu Sv \cdot h^{-1}$ ± 20 % above the background, when reaching the final position. The approach of the source shall start at least 5 m away from the instrument. The source shall move towards the instrument on a straight line, and stop at a final position placed at (1,0 ± 0,3) m from the reference point (see Figure C.1). The activity of the source needed is between 3,3 MBq and 11 MBq, the stopping point being adjusted to take into account the activity variation between sources. Before setup, the distance between the final position of the source and the reference point of the instrument shall be determined by dose rate measurement or calculation from the activity corresponding to the required dose rate of 0,5 $\mu Sv \cdot h^{-1}$.

Starting at a distance of at least 5 m, the source should move at a constant speed of 0,1 $m \cdot s^{-1}$ and stop at the final position. The photon source indication alarm shall be activated during approach or within 3 s after reaching the final position. The alarm shall then be acknowledged. After moving back the source, there shall be a break of at least 5 min to allow the instrument to adapt again to the background radiation level. After this break, the process shall be repeated nine additional times.

Results are acceptable when the alarm is activated in at least 8 out of 10 tests.

6.4 Photon safety alarm

6.4.1 Requirements

The instrument shall trigger a photon personal protection safety alarm within 3 s, when exposed to an increase in the dose rate at its reference point to a value of two times the threshold of the safety alarm. This requirement shall be met for ^{241}Am, ^{137}Cs, and ^{60}Co sources.

6.4.2 Method of test

Set the threshold of the photon safety alarm to a dose rate of 10 $\mu Sv \cdot h^{-1}$.

Using a ^{137}Cs source, increase the dose rate at the reference point of the instrument to 20 $\mu Sv \cdot h^{-1}$ ± 20 % within 1 s.

After the step change, the photon safety alarm shall be activated within 3 s. The alarm shall then be acknowledged, and the process repeated nine additional times. There shall be a break of at least 90 s between the exposures to allow the instrument to adapt again to background radiation level. Results are acceptable when the alarm is activated in 10 out of 10 exposures.

The test shall be repeated with a ^{241}Am source, and again with a ^{60}Co source.

When setting the alarm threshold to 10 $\mu Sv \cdot h^{-1}$, the allowed tolerance for the instruments response of ± 50 % (see 6.8) will result in a maximum true value of 15 $\mu Sv \cdot h^{-1}$ for the alarm threshold. Taking into account the ± 20 % tolerance of the exposure, the test is performed at a value of two times the alarm threshold.

6.5 Neutron source indication alarm

6.5.1 Requirements

Although the instrument is not intended to be used to search for neutron sources, it shall indicate the presence of a neutron source, when exposed to an increase of the neutron fluence rate of 3 neutrons·cm^{-2}·s^{-1} ± 20 % at its reference point, produced by an unmoderated ^{252}Cf source. The source shall be placed at a distance of at least 25 cm from the reference point. The instrument shall fulfil this requirement when worn on the body.

NOTE A ^{252}Cf neutron source emitting 24 000 neutrons·s^{-1} (approximately 0,01 µg or 0,2 MBq) would cause the required fluence rate of 3 neutrons·cm^{-2}·s^{-1} at 25 cm distance.

6.5.2 Method of test

This test shall be performed after the neutron false alarm test in 6.1 by using the same source alarm threshold settings as for the false alarm test. The instrument shall be mounted on a standard ICRU phantom as defined in 4.4.4.

From the background radiation level (see Table A.1), increase the neutron fluence rate at the reference point of the instrument by 3 neutrons·cm^{-2}·s^{-1} ± 20 % within 1 s by using an unmoderated ^{252}Cf source. The source shall be placed at a distance of at least 25 cm from the reference point.

After the step change, the neutron source indication alarm shall be activated within 20 s. The alarm shall then be acknowledged, and the process repeated nine additional times. There shall be a break of at least 90 s between the exposures to allow the instrument to adapt again to background radiation level. Results are acceptable when the alarm is activated at least 8 out of 10 exposures.

If the alarm threshold is adjusted to meet the requirements of this test, the FAR test (see 6.1) shall be repeated.

6.6 Neutron indication and response in the presence of photons

6.6.1 Requirements

The instrument shall not trigger a neutron source indication alarm when exposed to an increase in the photon dose rate of 100 µSv·h^{-1} at its reference point, caused by a ^{60}Co source.

Furthermore the neutron response (see 6.5) shall not be affected when the instrument is exposed to a photon dose rate of 100 µSv·h^{-1}.

NOTE This dose rate has been chosen as the highest value permissible for legal transports of radioactive material at a 1 m distance according to the IAEA Transport Regulations (transport index 10).

6.6.2 Method of test

This test shall be performed by using the same source indication alarm threshold settings as for the false alarm test (6.1).

Increase the photon dose rate at the reference point of the instrument to 100 µSv·h^{-1} ± 20 % within 1 s by using a ^{60}Co source.

No more than one neutron alarm shall be triggered during 10 min exposure.

To prove neutron sensitivity at the elevated photon dose rate, expose the instrument to the 100 µSv/h field produced by the ^{60}Co source, and repeat the test described in 6.5 and verify that the requirement in Clause 6.5 are fulfilled when the ^{60}Co source is present.

6.7 Neutron safety alarm

6.7.1 Requirements

The instrument shall trigger a neutron personal protection safety alarm within 3 s, when exposed to an increase in the neutron fluence rate at its reference point to a value of two times the threshold of the safety alarm. The increase in the neutron fluence rate shall be generated by an unmoderated ^{252}Cf source.

6.7.2 Method of test

Set the threshold of the neutron safety alarm to a value corresponding to a neutron dose rate of 50 μSv·h^{-1}. The relation between count rate and neutron dose rate provided by the manufacturer should be used for this purpose (see 5.8.4). The instrument shall be mounted on a standard ICRU phantom as defined in 4.4.4.

Using an unmoderated ^{252}Cf source and within 1 s, increase the neutron fluence rate at the reference point of the instrument to a value corresponding to a neutron dose rate of 100 μSv·h^{-1} ± 20 %.

After the step change, the neutron safety alarm shall be activated within 3 s. The alarm shall then be acknowledged and the process repeated nine additional times. There shall be a break of at least 90 s between the exposures to allow the instrument to adapt again to background radiation level. Results are acceptable when the alarm is activated in 10 out of 10 exposures.

When setting the alarm threshold to 50 μSv·h^{-1}, the allowed tolerance for the instruments response of ± 50 % (see 6.8) will result in a maximum true value of 75 μSv·h^{-1} for the alarm threshold. Taking into account the ± 20 % tolerance of the exposure, the test is performed at a value of two times the alarm threshold.

6.8 Photon dose rate – response

6.8.1 Requirements

The accuracy of the dose rate indication shall be within ± 50 % in the continuous photon energy range (see 5.3.3 for minimum requirement for this range). This requirement shall be met within the whole measurement range for the dose rate as stated by the manufacturer.

6.8.2 Method of test

Using a ^{137}Cs source, increase the dose rate at the reference point of the instrument to 1 μSv·h^{-1}, 10 μSv·h^{-1}, and 70 μSv·h^{-1}. If the manufacturer claims a dose rate measurement range larger than 1 μSv·h^{-1} to 100 μSv·h^{-1} then additional measurement points shall be introduced to the entire range in factors of 10 (e.g., 0,1 μSv·h^{-1} or 1000 μSv·h^{-1}). The highest testing point shall be 70 % from maximum of range.

The dose rate indication shall be within ± 50 % of the conventionally true dose rate value.

The test shall be repeated with a ^{241}Am source (or x-ray beam quality N-80 according to ISO 4037-3) and again with a ^{60}Co source.

6.9 Photon dose rate – over range

6.9.1 Requirements

The instrument shall indicate an over range condition within 3 s when the photon dose rate exceeds the maximum dose rate as stated by the manufacturer. The indication of the over-range condition shall still function at a dose rate of 10 times the stated maximum. The overload indication shall remain for the duration of the exposure. After the over-range

condition, the instrument shall respond normally within 5 min after the end of the exposure without the intervention of the user.

6.9.2 Method of test

Using a ^{137}Cs source, increase the dose rate at the reference point of the instrument within 1 s to twice the maximum as stated by the manufacturer or to 1 mSv·h^{-1} if there is no value stated by the manufacturer.

The instrument shall indicate an over range condition within 3 s of the step change and shall remain in that condition for the entire exposure period. After a minimum of 5 min exposure, reduce the dose rate to background value (see Table A.1). The instrument shall operate normally within 5 min after the end of exposure.

Repeat the whole test by applying a dose rate of 10 times the maximum stated by the manufacturer. There is no need to repeat the test if there is no over range value stated by the manufacturer.

6.10 Identification of single radionuclides

6.10.1 Requirements

The instrument shall be able to identify and categorize each of the following radionuclides (unshielded or shielded) within the time stated by the manufacturer with a maximum of 5 min (15 min for ^{40}K) when creating a dose rate of 1 μSv·h^{-1} at its reference point.

Nuclear materials:	LEU, HEU (may be indicated as U), WGPu (may be indicated as Pu)
Medical radionuclides:	^{67}Ga, ^{99m}Tc, ^{131}I, ^{201}Tl
Industrial radionuclides:	^{22}Na, ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu, ^{192}Ir, ^{241}Am
NORM:	^{40}K, ^{226}Ra, ^{232}Th

6.10.2 Method of test

Expose the instrument to the radionuclides listed in 6.10.1 one at a time. The source (unshielded or shielded) shall increase the dose rate at the instrument's reference point by 1 μSv·h^{-1} ± 30 % above background with a maximum measurement time of 5 min. For ^{40}K the test shall be performed with a dose rate at the instrument's reference point of 0,3 μSv·h^{-1} ± 30 % above background with a maximum measurement time of 15 min.

The test shall consist of 10 trials for each radionuclide (without shielding). The performance is acceptable when the instrument correctly identifies and categorizes the radionuclide within the time stated by the manufacturer with a maximum of 5 min (or 15 min for ^{40}K) in at least 8 out of 10 consecutive trials.

For radionuclides listed as medical, the test should be repeated with a shielding of 76 mm PMMA or similar plastic. For radionuclides listed as industrial or nuclear material, the test should be repeated with a shielding of 5 mm steel (inside) and additional 30 mm high density polyethylene (HDPE). The shielding shall completely surround the source. ^{241}Am should not be tested for the shielded case. For radionuclides listed as NORM, no particular shielded test is required, because they are employed as volume sources to emulate the self shielding of typical NORM load.

6.11 Identification of unknown radionuclides

6.11.1 Requirements

The instrument shall provide an indication such as "unknown", "unidentified" or "not in library", when exposed to the radiation of a radionuclide that is not in the library. The following

radionuclides shall be reported in such a way within the time stated by the manufacturer with a maximum of 5 min when creating a dose rate of 1 $\mu Sv \cdot h^{-1}$ at the instrument's reference point.

– ^{166m}Ho;
– ^{54}Mn.

Verify that the instrument library does not include ^{166m}Ho and ^{54}Mn. If possible, remove these radionuclides from the library before performing the test. If they cannot be removed, a different radionuclide not included in the library can be selected to perform the test.

6.11.2 Method of test

One at a time expose the instrument to the radionuclides listed in 6.11.1. The source shall increase the dose rate at the instrument's reference point by 1 $\mu Sv \cdot h^{-1} \pm 30$ % above background.

The test shall consist of 10 trials for each radionuclide. The performance is acceptable when the instrument indicates the radionuclide as "unknown", "unidentified" or "not in library" within 5 min in at least 8 out of 10 consecutive trials.

6.12 Simultaneous radionuclide identification

6.12.1 Requirements

The instrument shall be able to identify at least two radionuclides simultaneously. The following combinations shall be identified when each radionuclide increases the dose rate at the instrument's reference point by 1 $\mu Sv \cdot h^{-1}$ above background.

– $^{99m}Tc + ^{137}Cs$;
– $^{60}Co + ^{241}Am$;
– $^{133}Ba + ^{137}Cs$;
– $^{137}Cs + ^{226}Ra$.

6.12.2 Method of test

Expose the instrument to a pair of radionuclides listed in 6.12.1 simultaneously. Each radionuclide shall increase the dose rate at the instrument's reference point by 1 $\mu Sv \cdot h^{-1} \pm 30$ % above background.

The test shall consist of 10 trials for each pair. The performance is acceptable when the instrument correctly and simultaneously identifies both of the two radionuclides within the time stated by the manufacturer with a maximum of 5 min, in at least 8 out of 10 consecutive trials.

6.13 Masking

6.13.1 Requirements

The instrument shall be able to identify two radionuclides simultaneously even if one is present at a lower level masked by the other one appearing at a higher level.

The following combinations shall be identified when the first radionuclide increases the dose rate at the instrument's reference point by 1 $\mu Sv \cdot h^{-1}$ and the second by 2 $\mu Sv \cdot h^{-1}$ above background.

– HEU + ^{99m}Tc;
– WGPu + ^{131}I.

6.13.2 Method of test

Expose the instrument to a pair of radionuclides listed in 6.13.1 simultaneously. The first radionuclide of the pair shall increase the dose rate at the instrument's reference point by 1 $\mu Sv \cdot h^{-1}$ ± 30 % and the second one by 2 $\mu Sv \cdot h^{-1}$ ± 30 % above background.

The test shall consist of 10 trials for each pair. The test is passed, when both radionuclides are identified correctly or the first (SNM) radionuclide is identified correctly and the second (masking) radionuclide is identified as "unknown", within the time stated by the manufacturer with a maximum of 5 min in at least 8 out of 10 consecutive trials.

6.14 Range of dose rate for radionuclide identification

6.14.1 Requirements

Radionuclide identification should operate from the minimum up to the maximum dose rate stated by the manufacturer. If the manufacturer does not provide a range, the range stated in 5.3.5 shall apply. The instrument shall indicate if the dose rate is too low or too high for proper identification.

6.14.2 Method of test

Using ^{137}Cs, increase the dose rate at the instrument's reference point to 50 % above the minimum for radionuclide identification range as stated by the manufacturer and trigger a radionuclide identification. The instrument shall state, within 1 min, that the proper identification is not possible or correctly identify ^{137}Cs in at least 8 out of 10 trials.

Using ^{137}Cs, increase the dose rate at the instrument's reference point to 130 % above the minimum for radionuclide identification range as stated by the manufacturer and perform a radionuclide identification. The instrument shall correctly identify ^{137}Cs within 5 min in at least 8 out of 10 trials.

Using ^{137}Cs, increase the dose rate at the instrument's reference point to 70 % above the maximum for radionuclide identification range as stated by the manufacturer and perform a radionuclide identification. The instrument shall correctly identify ^{137}Cs within 5 min, in at least 8 out of 10 trials.

Using ^{137}Cs, increase the dose rate at the instrument's reference point to 200 % above the maximum for radionuclide identification range as stated by the manufacturer and trigger a radionuclide identification. The instrument shall state within 1 min that the proper identification is not possible or correctly identify ^{137}Cs in at least 8 out of 10 trials.

7 Environmental requirements

7.1 General requirements

The equipment shall comply with IEC 62706 concerning the environmental requirements for body worn instrumentation.

Environmental test procedures from IEC 62706 are used to define the environmental test conditions and shall be performed as stated in IEC 62706. Proper instrument operation under such test conditions is validated by using the functionality test defined by this standard (see 4.6). Such a functionality test has to be performed before and after an environmental test and in some cases also during the environmental testing (see Table 1).

The same procedure of combining a performance test from IEC 62706 and a functionality test from IEC 62618 (see 4.6) is applied for environmental, mechanical (see Clause 8), and electromagnetic (see Clause 9) testing.

7.2 Functionality test

The functionality test defined in 4.6 shall be applied to check proper instrument operation. Such functionality tests are performed at certain times before, during or after an environmental test, as stated in the environmental test matrix below.

7.3 Environmental test matrix

7.3.1 General

Environmental testing is performed by combining an environmental test from IEC 62706 with the functionality test from this standard. The following matrix (see Table 1) lists the required combinations of such tests and shows at what times during environmental testing the functionality tests are conducted.

Table 1 – Environmental test matrix

Environmental test (from IEC 62706)	Performance of functionality test (from 4.6 of IEC 62618)
7.2 Ambient temperature	• before temperature exposure (at 20 °C) • at maximum temperature after equilibrium time (30 min) • at minimum temperature after equilibrium time (30 min) • after temperature exposure (back at 20 °C) the instrument shall show regular operation behaviour as defined in 4.6.7 during testing
7.3 Temperature shock	• before the temperature shock (at 20 °C) • less than 15 min after exposure to maximum temperature (apply minimum time for stabilisation, as stated by the manufacturer) • less than 15 min after exposure to minimum temperature (apply minimum time for stabilisation, as stated by the manufacturer) • less than 15 min after returning to the nominal temperature (apply minimum time for stabilisation, as stated by the manufacturer) • 30 min after the temperature exposure (after equilibrium time) the instrument shall show regular operation behaviour as defined in 4.6.7 during testing
7.4 Relative humidity	• before environmental test • in the middle of each exposure (at a certain temperature or humidity level) • at the end of the environmental test
7.5 Low/high temperature start-up	• before environmental test • after warm-up time (low temperature) • after warm-up time (high temperature) the instrument shall show regular operation behaviour as defined in 4.6.7 during testing
7.6 IP classification (dust and moisture resistance)	• before environmental test • after environmental test the instrument shall show regular operation behaviour as defined in 4.6.7 during testing

7.3.2 Temperature range

The instrument shall operate over a temperature range stated by the manufacturer, which shall include the range stated in IEC 62706 for body worn instrumentation.

7.3.3 Equilibrium time

For the ambient temperature and the low/high temperature start-up test, the readings (or other functions of the instrument) shall be recorded after keeping the instrument at a constant temperature for the equilibrium time of 30 min.

7.3.4 Temperature shock

The instrument shall be able to function within a manufacturer-stated period of time following the exposure to a rapid change in temperature from nominal value to the high or low temperature value and back. The time required for an instrument to become functional after each temperature change shall be stated by the manufacturer up to the maximum value of 15 min.

8 Mechanical requirements

8.1 General requirements

The equipment shall comply with IEC 62706 concerning the mechanical requirements for body worn instrumentation.

Mechanical test procedures from IEC 62706 are used to define the mechanical test conditions and shall be performed as stated in IEC 62706. Proper instrument operation under such test conditions is validated by using selected test procedures from this standard as functionality tests. Such functionality tests have to be done before and after the mechanical tests (see Table 2).

8.2 Functionality test

The functionality test defined in 4.6 shall be applied to check proper instrument operation. Such functionality tests are performed at certain times before or after a mechanical, as stated in the mechanical test matrix below.

8.3 Mechanical test matrix

Mechanical testing is performed by combining a mechanical test from IEC 62706 with the functionality test selected from this standard. The following matrix (see Table 2) lists the required combinations of tests and shows at what times during mechanical testing the functionality tests are conducted.

Table 2 – Mechanical test matrix

Mechanical test (from IEC 62706)	Performance of functionality tests (from 4.6 of IEC 62618)
8.2 Drop	• before drop tests • after drop tests on all sides
8.3 Vibration test	• before vibration tests • after each vibration test in one of the three orthogonal directions the instrument shall show regular operation behaviour as defined in 4.6.7 during vibration testing
8.4 Microphonics/Impact	• before impact tests • after impact tests the instrument shall show regular operation behaviour as defined in 4.6.7 during impact testing
8.5 Mechanical shock	• before shock tests • after each set of 10 shocks in one of the three orthogonal directions

9 Electromagnetic requirements

9.1 General requirements

The equipment shall comply with IEC 62706 concerning the electromagnetic requirements for body worn instrumentation.

Electromagnetic test procedures from IEC 62706 are used to define the electromagnetic test conditions and shall be performed as stated in IEC 62706. Proper instrument operation under such test conditions is validated by using selected test procedures from this standard as functionality tests. Such functionality tests have to be done before, during and after the electromagnetic tests (see Table 3).

9.2 Functionality test

The functionality test defined in 4.6 shall be applied to check proper instrument operation. Such functionality tests are performed at certain times before, during or after an electromagnetic test, as stated in the electromagnetic test matrix below.

9.3 Electromagnetic test matrix

Electromagnetic compliance testing is performed by combining an electromagnetic test from IEC 62706 with the functionality test selected from this standard. The following matrix (see Table 3) lists the required combinations of tests and shows at what times during electromagnetic testing the functionality tests are conducted.

Table 3 – Electromagnetic test matrix

Electromagnetic test (from IEC 62706)	Performance of functionality tests (from 4.6 of IEC 62618)
9.2 Electrostatic discharge	• before discharge tests • after each set of ten discharges to a test point the instrument shall show regular operation behaviour as defined in 4.6.7 during discharge tests
9.3 Radio frequency Immunity	• before RF immunity test • continuously during RF sweep the instrument shall show regular operation behaviour as defined in 4.6.7 during RF immunity tests
9.4 Radiated RF emissions	no functionality test required during RF emission tests
9.5 Magnetic fields	• before magnetic field tests • after magnetic field tests the instrument shall show regular operation behaviour as defined in 4.6.7 during magnetic field tests

10 Documentation

10.1 General

This clause specifies the requirements for documentation.

10.2 Type test report or certificate

The manufacturer should provide a test report or certificate confirming that the instrument meets this standard.

10.3 Certificate

The manufacturer shall provide a certificate or other documentation in accordance with IEC 61187, containing at least the following information:

– the manufacturer's contact including name, address, telephone number, fax number, web-page and e-mail address;
– type of instrument (model number and serial number), type of detector, types of radiation the instrument is designed to measure and software version;
– mass and dimensions of the instrument;
– power supply (battery) requirements, including battery lifetime;
– operating temperature range;
– warm-up time;
– range of photon count rate and/or dose rate the instrument is designed to indicate;
– if applicable, range of neutron count rate and/or dose rate the instrument is designed to indicate;
– range of radionuclide identification count rate and/or dose rate the instrument is designed to measure; integration time for radionuclide identification;
– description of over range indication;
– default values of the alarm thresholds;
– list of radionuclides in the instrument library, including associated categories;
– location and dimensions of the sensitive volumes of the detectors;
– reference point and reference orientation for reference sources used for calibration and testing;
– response of the instrument to different appropriate radiation energies;
– response of the instrument to different incident angles;
– results of tests for accuracy, linearity and lower limit of detection;
– declaration of conformity with respect to this standard, IEC 62618.

10.4 Operation and maintenance manuals

Each instrument shall be supplied with operating instructions, maintenance and technical documentation. The manufacturer shall supply an operational and maintenance manual containing at least the following information for the user:

– operating instructions and restrictions;
– instrument orientation for use;
– maintenance instructions and testing procedures;
– troubleshooting guide;
– schematic electrical diagrams including spare parts list (if applicable);
– description of methods and communication protocol for transmitting and receiving data.

Annex A
(normative)

Test conditions

Table A.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 photon radiation source	^{241}Am, ^{137}Cs, ^{60}Co	^{241}Am, ^{137}Cs, ^{60}Co
Reference neutron radiation source (unmoderated)	^{252}Cf	^{252}Cf
Photon background - ambient dose equivalent rate	0,1 μSv·h^{-1}	0,1 μSv·h^{-1} ± 50 %
Neutron background ambient fluence	0,015 neutrons·s^{-1}·cm^{-2}	0,015 neutrons·s^{-1}·cm^{-2} ± 50 %
Angle of incidence of radiation	Reference direction given by the manufacturer	Direction given ± 5°
Warm-up time	As stated by manufacturer	As stated by manufacturer (less than 10 min – see 5.3.6)
Ambient temperature	20 °C	18 °C to 22 °C [a)]
Relative humidity	65 %	50 % to 75 % [a)]
Atmospheric pressure	101,3 kPa	70 kPa to 106 kPa [a)]
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to earth's magnetic field
Instrument controls	Set-up for normal operation	Set-up for normal operation
Contamination by radionuclides	Negligible	Negligible

a) The values in the table are intended for tests performed in temperate climates. In other climates the actual values of the quantities at the time of test shall be stated. Similarly a lower limit of pressure of 70 kPa may be permitted at higher altitudes.

NOTE The characteristics of, and dosimetry methods for, the reference photon radiations are given in ISO 4037-1, 2 and 3. The characteristics of, and dosimetry methods for, the reference neutron radiations are given in ISO 8529-1, 2 and 3.

Annex B
(normative)

Performance

Table B.1 – Summary of tests and performance requirements *(1 of 2)*

Characteristic under test	Performance requirement	Relevant clause or subclause
False alarm rate	background dose rate of 0,1 $\mu Sv \cdot h^{-1}$ ± 50 %; not more than 3 photon and 3 neutron (if applicable) false alarms during 8 h operation;	6.1
Photon source indication alarm	dose rate increase of 0,5 $\mu Sv \cdot h^{-1}$ ± 20 % by ^{241}Am, ^{137}Cs, ^{60}Co within 1 s; alarm indication within 3 s; at least 8 out of 10 tests;	6.2
Photon indication – detection of gradually increasing radiation levels	dose rate increase of 0,5 $\mu Sv \cdot h^{-1}$ ± 20 % by ^{241}Am, ^{137}Cs, ^{60}Co by approaching at a speed of 0,1 $m \cdot s^{-1}$; alarm indication within 3 s; at least 8 out of 10 tests;	6.3
Photon safety alarm	alarm threshold set to 10 $\mu Sv \cdot h^{-1}$; dose rate increased to 20 $\mu Sv \cdot h^{-1}$ ± 20 % by ^{241}Am, ^{137}Cs, ^{60}Co within 1 s; alarm indication within 3 s; 10 out of 10 tests;	6.4
Neutron source indication (if applicable)	neutron fluence rate increase of 3 neutrons $\cdot cm^{-2} \cdot s^{-1}$ ± 20 % by unmoderated ^{252}Cf within 1 s; alarm indication within 20 s; at least 8 out of 10 tests;	6.5
Neutron indication and response in the presence of photons	photon dose rate of 100 $\mu Sv \cdot h^{-1}$ ± 20 % by ^{60}Co within 1 s; not more than one neutron alarm within 10 min exposure; still same neutron sensitivity as defined in 6.5;	6.6
Neutron safety alarm (if applicable)	alarm threshold set corresponding to 50 $\mu Sv \cdot h^{-1}$; dose rate increased to 100 $\mu Sv \cdot h^{-1}$ ± 20 % by unmoderated ^{252}Cf within 1 s; alarm indication within 3 s; 10 out of 10 tests;	6.7

Table B.1 *(2 of 2)*

Characteristic under test	Performance requirement	Relevant clause or subclause
Photon dose rate – response	± 50 % for ^{241}Am, ^{137}Cs, ^{60}Co at a dose rate of 1 μSv·h^{-1}, 10 μSv·h^{-1}, 70 μSv·h^{-1} (complemented according to measurement range);	6.8
Photon dose rate - over range	dose rate of 2x, 10x max. range or 1 mSv·h^{-1} by ^{137}Cs; alarm and over range indication within 3 s and during 5 min exposure; recovered after 5 min;	6.9
Identification	LEU, HEU, WGPu, ^{67}Ga, ^{99m}Tc, ^{131}I, ^{201}Tl, ^{22}Na, ^{57}Co, ^{60}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu, ^{192}Ir, ^{241}Am, ^{40}K, ^{226}Ra, ^{232}Th; 1 μSv·h^{-1} ± 30 % at reference point; identification within 5 min (15 min at 0,3 μSv·h^{-1} for ^{40}K); categorisation; at least 8 out of 10 test;	6.10
Identification of unknown radionuclides	^{166m}Ho, ^{54}Mn; 1 μSv·h^{-1} ± 30 % at reference point; indicated as not in library within 5 min; at least 8 out of 10 tests;	6.11
Simultaneous radionuclide identification	^{99m}Tc + ^{137}Cs, ^{60}Co + ^{241}Am, ^{133}Ba + ^{137}Cs, ^{137}Cs + ^{226}Ra each 1 μSv·h^{-1} ± 30 %; identification within 5 min; at least 8 out of 10 test;	6.12
Masking	HEU + ^{99m}Tc, WGPu + ^{131}I first 1 μSv·h^{-1} ± 30 %, second 2 μSv·h^{-1} ± 30 %; identification within 5 min; at least 8 out of 10 test;	6.13
Range of dose rate for radionuclide identification	50, 130 % of min. and 70, 200 % of max. dose rate from ID range by ^{137}Cs; at least 8 identifications in 10 tests	6.14
Functionality test	^{241}Am and ^{60}Co; each 2 μSv·h^{-1} ± 50 % at reference point; drift below 30 %; drift of energy calibration less than 3 %; unmoderated ^{252}Cf (if applicable); 20 neutrons·cm^{-2}·s^{-1} ± 50 % at reference point; drift below 30 %;	4.6
Environmental requirements	environmental tests from IEC 62706 for the class “body worn”	4.6, 7
Mechanical requirements	mechanical tests from IEC 62706 for the class “body worn”	4.6, 8
Electromagnetic requirements	electromagnetic tests from IEC 62706 for the class “body worn”	4.6, 9

Annex C
(informative)

Test geometry

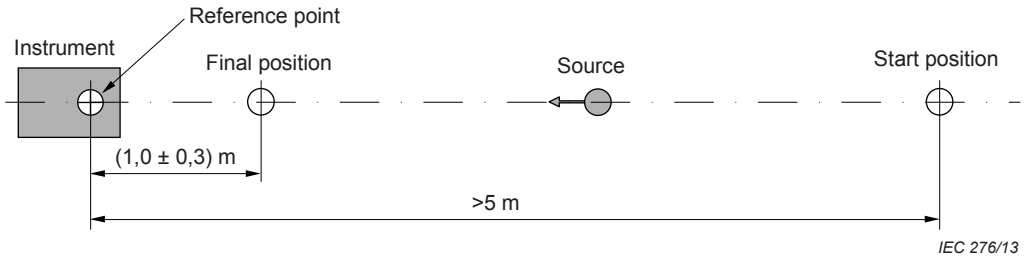

Figure C.1 – Geometry for testing photon source indication alarm

Annex D
(informative)

SNM categorization

The following Table D.1 provides background information regarding the detection and identification of various grades of uranium that may be transported and cause alarms to occur as a result of measurements performed using instruments addressed by this standard.

Table D.1 – Categorization of special nuclear material

Grade	Definition	Accepted categories	Acceptable identification	Comment
U ore	Natural U, i.e. ^{235}U and ^{238}U in natural abundance and in secular equilibrium	NORM	^{226}Ra	It is difficult to distinguish U ore from ^{226}Ra and daughters because they are part of the ^{238}U decay chain and the 186,2 keV ^{226}Ra peak is masking the 185,7 keV main peak of ^{235}U
Refined U	Natural U chemically processed to be separated from daughters (^{234}Th and ^{234m}Pa being short lived daughters of ^{238}U are still present)	SNM	U, ^{235}U, or ^{235}U + ^{238}U	There is no practical way for this application to distinguish refined U from slightly enriched U. Because of this, refined U should be categorized as SNM.
Low enriched uranium (LEU)	Enriched U up to a ^{235}U concentration of 20 % ^{235}U.	SNM	U, LEU, ^{235}U, or ^{235}U + ^{238}U	May include a sub-class that could indicate slightly enriched uranium U enriched to a ^{235}U concentration of 0,9 % to 2 %.
High enriched uranium (HEU)	Enriched U up to a ^{235}U concentration at higher than 20 % ^{235}U	SNM	U, HEU, ^{235}U, or ^{235}U + ^{238}U	
Depleted uranium (DU)	U with lower than natural abundance of ^{235}U	SNM, or industrial	U, DU, ^{235}U + ^{238}U, or ^{238}U	Although DU is not typically considered an SNM, DU will generally be categorized as SNM due to its hazards and also its masking capability.

Typical isotope composition (enrichment)

HEU contains ≥ 90 % ^{235}U, DU contains about 0,2 % ^{235}U, RGPu contains > 6 % ^{240}Pu and WGPu contains ≤ 6 % ^{240}Pu.

Annex E
(informative)

List of expected daughters and impurities

The IAEA recommends the following characterisation scheme to assess the correctness of the radionuclide identification:

a) Complete & Correct (C&C):

– Source "X" identified as "X";
– Sources "X+Y" identified as "X+Y".

For example:
– $^{235}U \rightarrow {}^{235}U$;
– $^{235}U \rightarrow {}^{235}U + {}^{40}K$;
– $^{235}U \rightarrow {}^{235}U + {}^{40}K + {}^{232}Th$;
– $^{235}U \rightarrow {}^{235}U + {}^{40}K + {}^{232}Th + {}^{226}Ra$;
– $^{235}U + {}^{67}Ga \rightarrow {}^{235}U + {}^{67}Ga + {}^{40}K + {}^{232}Th + {}^{226}Ra$.

Complete and Correct may also include progeny and impurities of the target radionuclide(s). NORM radionuclides can be displayed as they are part of the background even when they are not part of the source being tested. Table E.1 provides a list of progeny and expected impurities.

b) Incomplete

– Source "X+Y" identified as "X" or "Y"

For example:
– $^{235}U + {}^{226}Ra \rightarrow {}^{226}Ra$

c) Incorrect

– Source "X" identified as "X + Y".

For example:
– $^{235}U \rightarrow {}^{235}U + {}^{237}Np$
– $^{67}Ga \rightarrow {}^{235}U + {}^{67}Ga$

d) Incomplete & Incorrect (I&I)

– Source “A” being identified as “C”
– Source "A+B" identified as "C+D"

For example:
– $^{235}U \rightarrow {}^{67}Ga$
– $^{235}U + {}^{137}Cs \rightarrow {}^{99m}Tc + {}^{133}Ba$

The list of expected progeny and known impurities is given below. If a radionuclide is not listed that means that there are no expected daughters for that particular radionuclide. Therefore, the required radionuclide is the one present.

NOTE Some systems do not distinguish the plutonium and uranium enrichment, in those cases these different sources are identified using the same radionuclide or source name.

Table E.1 – List of acceptable daughters and expected impurities

Source	Required radionuclide	Expected daughters or known impurities
^{201}Tl	^{201}Tl	^{202}Tl
DU	^{238}U	^{235}U, ^{226}Ra
RGPu	^{239}Pu	^{242}Pu, ^{241}Pu, ^{240}Pu, ^{238}Pu, ^{241}Am, ^{237}U, ^{242}Pa, ^{233}U, neutron, ^{252}Cf, ^{249}Cf, RGPu, Plutonium
WGPu	^{239}Pu	^{242}Pu, ^{241}Pu, ^{240}Pu, ^{238}Pu, ^{241}Am, ^{237}U, ^{242}Pa, ^{233}U, neutron, ^{252}Cf, ^{249}Cf, WGPu, Plutonium
HEU	^{235}U	^{238}U, ^{234m}Pa, HEU , Uranium
(^{226}Ra + ^{232}Th)+WGPu	^{239}Pu	^{242}Pu, ^{241}Pu, ^{240}Pu, ^{238}Pu, ^{241}Am, ^{237}U, ^{242}Pa, ^{233}U, neutron, ^{252}Cf, ^{249}Cf, ^{228}Th, ^{232}U, ^{214}Bi, ^{214}Pb, ^{232}Th, ^{226}Ra, WGPu, Plutonium
(^{226}Ra + ^{232}Th) + HEU	^{235}U	^{238}U, ^{234m}Pa, ^{228}Th, ^{232}U, ^{214}Bi, ^{214}Pb, ^{232}Th, ^{226}Ra, HEU, Uranium
^{131}I+ WGPu	^{239}Pu + ^{131}I	^{242}Pu, ^{241}Pu, ^{240}Pu, ^{238}Pu, ^{241}Am, ^{237}U, ^{242}Pa, ^{233}U, neutron, ^{252}Cf, ^{249}Cf, WGPu, Plutonium
^{99m}Tc+ HEU	^{235}U + ^{99m}Tc	^{238}U, ^{234m}Pa, ^{99}Mo, HEU, Uranium
^{99m}Tc	^{99m}Tc	^{99}Mo
^{232}Th	^{232}Th	^{228}Th, ^{232}U
^{226}Ra	^{226}Ra	^{214}Bi, ^{214}Pb

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

IEC 61005, *Radiation protection instrumentation – Neutron ambient dose equivalent (rate) meters*

IEC 61526, *Radiation protection instrumentation – Measurement of personal dose equivalents Hp(10) and Hp(0,07) for X, gamma, neutron and beta radiations – Direct reading personal dose equivalent meters*

IEC 62327, *Radiation protection instrumentation – Hand-held instruments for the detection and identification of radionuclides and for the indication of ambient dose equivalent rate from photon radiation*

IEC 62401, *Radiation protection instrumentation – Alarming Personal Radiation Devices for detection of illicit trafficking of radioactive material*

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

ISO 4037-2, *X and gamma reference radiation 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*

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

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