IEC 62618

Edition 2.0 2022-11

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 de matières radioactives

IEC 62618:2022-11(en-fr)

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

FOREWORD

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

This second edition cancels and replaces the first edition published in 2013. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) making the standard consistent with the new standards for detection of illicit trafficking of radioactive material (see the Introduction);
b) creating unformed functionality test for all environmental, electromagnetic and mechanical tests and a requirement for the coefficient of variation of each nominal mean reading;
c) reference to IEC 62706 for the environmental, electromagnetic and mechanical test conditions;
d) adding information regarding climatic exposures.

The text of this International Standard is based on the following documents:

Draft	Report on voting
45B/1011/FDIS	45B/1017/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- withdrawn,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

INTRODUCTION

It is important to detect illicit and inadvertent movement of radioactive materials in the form of radiation sources and contaminated metallurgical scrap. Radioactive sources out of regulatory control, so-called “orphan sources”, have frequently caused serious radiation exposures and widespread contamination. Although illicit trafficking of nuclear and other radioactive materials is not a new problem, concern about a nuclear “black market” has increased particularly in view of its terrorist potential.

In response to the technical policy of the International Atomic Energy Agency (IAEA), the World Customs Organization (WCO), and the International Criminal Police Organization (Interpol) related to the detection and identification of special nuclear materials and security trends, nuclear instrumentation companies have developed and manufactured radiation instrumentation to assist in the detection of illicit movement of radioactive and special nuclear materials. This type of instrumentation is widely used for security purposes at nuclear facilities, border control checkpoints, and international seaports and airports.

To ensure that measurement results made at different locations are consistent, it is imperative that radiation instrumentation be designed to specifications based upon agreed performance requirements. IEC standards have been developed to establish performance requirements for personal radiation detectors, radiation portal monitors, highly sensitive gamma and neutron detection systems, spectrometric personal radiation detectors, and backpack-based radiation detection and identification systems. Table 1 contains a list of those standards.

Table 1 – Overview of IEC radiation protection instrumentation standards

Type of instrumentation	IEC number	Title of the standard
Body-worn	**62401**	Radiation protection instrumentation – Alarming Personal Radiation Devices (PRDs) for the detection of illicit trafficking of radioactive material
	62618	Radiation protection instrumentation – Spectroscopy-Based Alarming Personal Radiation Detectors (SPRD) for the detection of illicit trafficking of radioactive material
	62694	Radiation protection instrumentation – Backpack-type radiation detector (BRD) for the detection of illicit trafficking of radioactive material
Portable or hand-held	**62327**	Radiation protection instrumentation – Hand-held instruments for the detection and identification of radionuclides and for the estimation of ambient dose equivalent rate from photon radiation
	62533	Radiation protection instrumentation – Highly sensitive hand-held instruments for photon detection of radioactive material
	62534	Radiation protection instrumentation – Highly sensitive hand-held instruments for neutron detection of radioactive material
Portal	**62244**	Radiation protection instrumentation – Installed radiation portal monitors (RPMs) for the detection of illicit trafficking of radioactive and nuclear materials
	62484	Radiation protection instrumentation – Spectrometric radiation portal monitors (SRPMs) used for the detection and identification of illicit trafficking of radioactive material
Data format	**62755**	Radiation protection instrumentation – Data format for radiation instruments used in the detection of illicit trafficking of radioactive materials
Mobile system	**63121**	Radiation protection instrumentation – Vehicle-mounted mobile systems for the detection of illicit trafficking of radioactive materials

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

1 Scope

This document applies to Spectroscopy-based alarming Personal Radiation Detectors (SPRD). SPRDs detect and identify gamma radiation and may detect neutron radiation. SPRDs can be worn on a belt or in a pocket to alert the wearer of the presence of a radiation source. SPRDs provide search, similar to that of a Personal Radiation Device (PRD), and identification capability to identify radiation sources. They can discriminate between alarms caused by Naturally Occurring Radioactive Materials (NORM) or medical radionuclides and alarms from industrial sources or Special Nuclear Material (SNM).

This document establishes performance requirements and specifies general characteristics, general test conditions, radiological, climatic, mechanical, and electromagnetic characteristics. This document also provides test methods that are used to determine if an SPRD meets the stated requirements.

This document does not apply to the performance of radiation protection instrumentation which is covered in IEC 61526 and IEC 60846-1. SPRDs are not intended for accurate measurement of personal ($H_p(10)$) or ambient ($H^*(10)$) dose equivalent (rate).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-395:2014, *International Electrotechnical Vocabulary (IEV) – Part 395: Nuclear instrumentation – Physical phenomena, basic concepts, instruments, systems, equipment and* detectors
IEC 60050-395:2014/AMD1:2016
IEC 60050-395:2014/AMD2:2020

IEC 60079-11, *Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"*

IEC 62706, *Radiation protection instrumentation – Recommended climatic, electromagnetic and mechanical performance requirements and methods of tests*

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

IEC TR 62971:2015, *Radiation instrumentation – Radiation sources used in illicit trafficking detection standards – Guidance and recommendations*

UL 913, *Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, III, Division 1, Hazardous (Classified) Locations*

ICRU report 39, *Determination of Dose Equivalents Resulting from External Radiation Sources*

ICRU report 47, *Measurement of Dose Equivalents from External Photon and Electron Radiations*

3 Terms and definitions, abbreviated terms and symbols, quantities and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-395, as well as the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
acceptable identification
correct identification
when an instrument correctly identifies only the radionuclides 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 60050-395:2014/AMD2:2020, 395-16-14]

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

3.1.4
alarm criteria
condition that causes an instrument to alarm

3.1.5
background radiation level
radiation field in which there are no external radioactive sources present other than those in the natural background at the location of the measurements

3.1.6
confidence indication
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.

3.1.7
coefficient of variation
ratio of the standard deviation σ to the arithmetic mean $\overline{x}$ of a set of n measurements x_i given by the following formula:

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

3.1.8
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.

3.1.9
false alarm
alarm not caused by an increase in radiation level over background conditions

3.1.10
functionality test
procedure to measure potential changes in the instrument response, such as drift in energy calibration or sensitivity

3.1.11
influence quantity
quantity that is not the measurand but that affects the result of the measurement

Note 1 to entry: For example, temperature of a micrometer used to measure length.

3.1.12
precision
degree to which repeated measurements under unchanged conditions show the same result (also called reproducibility or repeatability)

3.1.13
radioactive material
material containing one or more constituents exhibiting radioactivity

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

3.1.14
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.

3.1.15
reference source
radioactive secondary standard source for use in calibration of the measuring instrument

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

3.1.16
relative intrinsic error
difference between the instrument's reading, M, and the conventionally true value, CTV, of the quantity being measured divided by the conventionally true value when subjected to a specified reference quantity under specified reference conditions

$$\varepsilon_{REL} = \frac{M - CTV}{CTV}$$

3.1.17
safety alarm
audible and visual signal for detection of high radiation levels, which requires immediate radiation safety measures

3.1.18
source indication alarm
audible and/or visual signal to indicate the presence of a radiation source

3.1.19
standard test conditions
range of values of a set of influence quantities under which a test, calibration or measurement of response is carried out

3.1.20
performance test
environmental, mechanical or electrical test taken from IEC 62706

[SOURCE: IEC 60050-395:2014/AMD2:2020, 395-14-9]

3.2 Abbreviated terms and symbols

CISPR	Comité International Spécial des Perturbations Radioélectriques (Special International Committee on Radio Interference)
CLYC	Cs_2LiYCl_6:Ce
COV	coefficient of variation
CZT	cadmium zinc telluride
DU	depleted uranium
ESD	electrostatic discharge
HDPE	highly-density polyethylene
HEU	highly-enriched uranium
ICRU	International commission on radiation units and measurements
NORM	naturally occurring radioactive material
PMMA	polymethyl methacrylate
RF	radio frequency
SNM	special nuclear material
SPRD	spectroscopy based personal radiation detector
WGPu	weapons-grade plutonium

3.3 Quantities and units

In this document, units of the International System (SI) are used[1]. The definitions of radiation quantities are given in IEC 60050-395.

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

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);
– for temperature: degrees Celsius (symbol: °C), 0 °C = 273,15 K.

Multiples and submultiples of SI units are used, when practicable, according to the SI system.

4 General test procedure

4.1 Standard test conditions

Except where otherwise specified, the tests described in this document should be performed under the standard test conditions given in Table 2. The ambient temperature, relative humidity, and atmospheric pressure shall be recorded during testing.

Table 2 – Standard test conditions

Influence quantity	Standard test conditions
Ambient temperature	18 °C to 25 °C
Relative humidity	≤ 75 %
Atmospheric pressure	70 kPa to 103,3 kPa
Gamma radiation background	Ambient dose equivalent rate less than or equal to 0,15 μSv•h^{-1} Natural conditions without the presence of man-made emitters
Neutron background	Natural conditions without the presence of man-made emitters

NOTE SPRDs are typically used in non-radiological areas, e.g., shipping ports and border locations. Man-made radiological materials such as radiation sources are not expected to be present in these areas. Non-radiological areas are expected to be used when testing SPRDs.

4.2 Uncertainties

Unless otherwise stated for a specific quantity, the uncertainties for measurable quantities should not exceed 15 % with a coverage factor of k = 1, except for background radiation measurements that may exceed this value.

4.3 Statistical fluctuations

For tests involving the use of radioactive sources to verify susceptibility to a climatic, electromagnetic, or mechanical condition (Clauses 7, 8, and 9), the radiation field produced by the sources to verify an SPRD's response shall be adjusted to reduce the magnitude of the statistical fluctuations.

For measurements without sources (i.e., at the level of background radiation), the SPRD is observed in order to verify that alarms and spurious indications are not produced by an influence quantity (e.g., temperature, humidity, RF, impact, vibration), as readings are expected to display large fluctuations.

4.4 Background radiation during testing

Testing shall be performed in an area having a radiation background as defined in Table 2. The background shall be measured prior to testing and monitored during testing. A background spectrum shall also be acquired using a high-resolution gamma-ray spectroscopy (e.g., high-purity germanium [HPGe]) detector to ensure that only naturally-occurring radionuclides (e.g., ^{40}K, ^{232}Th series, ^{238}U series) are present in the testing area. The neutron background should be measured unless it can be confirmed that no neutron sources are in the test area. The elevation of the test location shall be recorded.

4.5 Operating parameters and set up

SPRDs shall be set up based on the manufacturer's specifications. Operating parameters such as alarm settings should remain unchanged throughout the test.

For testing purposes, the reference point of the SPRD is the centre of the front face unless otherwise defined by the manufacturer. If the SPRD requires a background measurement, it shall be allowed to acquire the data in a manner specified by the manufacturer prior to the start of a test.

4.6 Radiation sources

For alarm tests, an ambient dose equivalent rate level of 0,5 μSv•h^{-1} (-0 %, +20 %) above background for ^{241}Am, ^{137}Cs, and ^{60}Co is used. For identification tests, an ambient dose equivalent rate level of 1,0 μSv•h^{-1} (-0 %, +20 %) above background for DU, HEU, WGPu, ^{137}Cs, ^{60}Co, ^{67}Ga, ^{131}I, ^{99m}Tc, ^{201}Tl is used. The ambient dose equivalent rate can be calculated or measured and shall be documented.

^{252}Cf, ^{244}Cm or ^{248}Cm is the reference source for neutron alarm testing. The source shall have a neutron emission rate of 20 000 s^{-1} (−10 %, +40 %) and, unless otherwise stated, be surrounded by a high-density polyethylene (HDPE) moderator (density between 0,93 g·cm^{-3} to 0,97 g·cm^{-3}). The HDPE moderator can be spherical or cylindrical and shall have a wall thickness of 4 cm on all sides and an inner cavity no larger than 3 cm in diameter or length. The source shall be positioned at the centre of the cavity.

The medical radionuclides (^{99m}Tc, ^{67}Ga, ^{131}I, and ^{201}Tl) shall be surrounded by 8 cm of PMMA for test purposes as a means to represent in-vivo conditions, the ambient dose equivalent rate is measured outside the PMMA.

4.7 Special nuclear material (SNM) and depleted uranium (DU) sources

Different masses, shapes, and forms may be used for testing as long as the required ambient dose equivalent rate is obtained. For this document, highly-enriched uranium (HEU) has an enrichment that is ≥90 % ^{235}U, depleted uranium (DU) has a ^{235}U abundance of 0,2 % to 0,4 %, and weapons-grade plutonium (WGPu) has a composition of ≤6,5 % ^{240}Pu and >93 % ^{239}Pu.

The 60 keV ^{241}Am emission rate shall not be more than a factor of 10 greater than the 375 keV ^{239}Pu emission rate. The shielding shall reduce the 60 keV ^{241}Am emission rate so that it is not more than a factor of 10 greater than the 375 keV ^{239}Pu emission rate.

NOTE The factor 10 is determined from source material measurements.

4.8 Speed of moving sources including scaling

For dynamic tests, the source or SPRD shall be moved in a configuration that provides no shielding around the source other than that required for the specific test. The source speed shall be 1 m·s^{-1} when tested at a distance of closest approach of 1,5 m, unless otherwise required in a test.

During the dynamic tests, there shall be a 10 s minimum delay, unless otherwise stated, between each trial with the source positioned at a distance where it does not affect the background surrounding the SPRD. Shielding can be used to reduce the background at the SPRD.

To achieve the required ambient dose equivalent rate at the test point, the distance of closest approach, d, can be adjusted within a range of 0,5 m and 3 m. If the distance of closest approach, d_0, is modified then the passage speed, v, shall be adjusted to:

$$v = v_0 \frac{d}{d_0} \quad (1)$$

where

v_0 = 1 m·s^{-1}, and

d_0 = 1,5 m.

4.9 Functionality test and test acceptance range requirements

4.9.1 General requirements

For most tests in Clauses 7, 8, and 9, the SPRD functionality is evaluated prior to and after the test and in some cases during the test. The response of the SPRD after the test (post-test measurement) is compared with the response prior to the test (pre-test measurement).

When applicable, depending on the test method, the source shall be kept in the same location throughout the duration of the test (pre-test measurements through post-test measurements). Otherwise, if the source needs to be removed during the test, to account for any possible bias introduced by the source placement, the source shall be placed at the same location used for the pre-test measurements.

Gamma-ray measurements are performed using ^{241}Am and ^{60}Co sources (or other sources that emit low- and high-energy gamma-rays) and the neutron measurements are performed using a neutron source, e.g., ^{252}Cf, ^{244}Cm, ^{248}Cm, or ^{241}AmBe. The ^{241}Am and ^{60}Co sources should be positioned so that the COV of each nominal mean reading is less than or equal to 12 %. The following guidance regarding sources applies:

- The same sources shall be used in the pre- and post-tests.
- The sources should activate the appropriate alarms during the pre-test measurements.
- For identification verification, the dead time should be small (e.g., less than 5 %) in order to avoid pile-up effects.

The pre-test, intermediate-test, and post-test measurements shall be carried out on the instrument under test as follows.