IEC 62694

Edition 2.0 2022-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Radiation protection instrumentation – Backpack-type radiation detector (BRD) for the detection of illicit trafficking of radioactive material

Instrumentation pour la radioprotection – Détecteur de rayonnement de type sac à dos (BRD) pour la détection du trafic illicite des matières radioactives

IEC 62694:2022-11(en-fr)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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CONTENTS

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RADIATION PROTECTION INSTRUMENTATION – BACKPACK-TYPE RADIATION DETECTOR (BRD) FOR THE DETECTION OF ILLICIT TRAFFICKING OF RADIOACTIVE MATERIAL

FOREWORD

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IEC 62694 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 2014. 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;
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) revised radiological requirements including the simplification of radionuclide identification acceptance criteria;
d) reference to IEC 62706 for the environmental, electromagnetic and mechanical test conditions.

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

Draft	Report on voting
45B/1012/FDIS	45B/1018/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/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.

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INTRODUCTION

Radioactive sources out of regulatory control, so-called “orphan sources”, have frequently caused serious radiation exposures and widespread contamination. Although illicit trafficking in nuclear and other radioactive materials is not a new phenomenon, concern about a nuclear “black market” has increased particularly in view of its terrorist potential.

In response to the technical policy of agencies such as 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 are developing and manufacturing 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, international seaports, airports, and major events.

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, vehicle mounted mobile systems, and backpack-based radiation detection and identification systems. A list of those standards is given below.

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 Devices (SPRDs) 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 – BACKPACK-TYPE RADIATION DETECTOR (BRD) FOR THE DETECTION OF ILLICIT TRAFFICKING OF RADIOACTIVE MATERIAL

1 Scope

This document applies to backpack-type radiation detectors (BRDs) that are primarily used for the detection of illicit trafficking of radioactive material. BRDs are portable instruments designed to be worn during use. BRDs detect gamma radiation and may include neutron detection and the ability to identify gamma-ray emitting radionuclides.

This document establishes the operational and testing requirements associated with radiation measurements and the expected electrical, mechanical, and environmental conditions while in use.

This document does not apply to ambient or personal dose equivalent rate meters which are covered in IEC 60846-1 or IEC 61526, respectively.

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
IEC60050-395:2014/AMD1:2016
IEC 60050-395:2014/AMD2:2020

IEC 60068-2-11, *Environmental testing – Part 2-11: Tests – Test Ka: Salt mist*

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*

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

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 terminological databases for use in standardization at the following addresses:

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

3.1.1
alarm
audible, visible, or other signal activated when the instrument reading exceeds a pre-set value, falls outside of a pre-set range, or when the instrument detects the presence of the source of radiation according to a pre-set condition

3.1.2
background 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

3.1.3
backpack-type radiation detector
instrument composed of several radiation detection components that are placed inside a backpack or other similar enclosure with an external user interface or control device

3.1.4
coefficient of variation
COV
ratio of the standard deviation s to the arithmetic mean $\bar{x}$ of a set of n measurements x_i given by the following formula:

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

3.1.5
fluence
Φ
quotient of dN by da, where dN is the number of particles incident on a sphere of cross-sectional area da: $\Phi = dN/da$

3.1.6
fluence rate
$\dot{\phi}$
quotient of $d\Phi$ by dt, where $d\Phi$ is the increment of the fluence in the time interval dt, thus $\dot{\phi} = \frac{d\phi}{dt}$

Note 1 to entry: The unit of fluence rate is $m^{-2} \cdot s^{-1}$.

3.1.7
type test
conformity test made on one or more items representative of the production

3.1.8
user interface
software and/or hardware that manages interactions between a user and equipment

3.1.9
variance
σ^2
measure of dispersion, which is the sum of the squared deviation of observations from their mean divided by one less than the number of observations

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

3.2 Abbreviated terms and symbols

BRD	backpack-type radiation detector
COV	coefficient of variation
cps	counts per second
DU	depleted uranium
ESD	electrostatic discharge
GPS	global positioning system
HDPE	high-density polyethylene
HEU	highly-enriched uranium
HPGe	high purity germanium
ICRU	International commission on radiation units and measurements
NORM	naturally occurring radioactive material
PMMA	polymethyl methacrylate
r	radius
RF	radio frequency
SNM	special nuclear material
WGPu	weapons-grade plutonium
XML	eXtensible Markup Language

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.

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.

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

4 General test procedure

4.1 General

Unless otherwise specified in an individual step, tests enumerated in this document may be used as part of a type test or an acceptance test.

4.2 Standard test conditions

Except where otherwise specified, the tests described in this document should be performed under the standard test conditions given in Table 1. The ambient temperature, relative humidity, and atmospheric pressure shall be recorded during testing.

Table 1 – 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 Neutron sources at levels that could affect the performance of a test shall not be in the test area

NOTE BRDs 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. Open indoor spaces are expected to be used when performing most of the tests described in this document.

4.3 Uncertainties

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

4.4 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 a BRD’s response shall be adjusted to reduce the magnitude of the statistical fluctuations.

If the magnitude of the statistical fluctuations arising from the random nature of radiation alone is a significant fraction of the variation of the indication permitted in the test (i.e., fluctuations greater than 12 %), then the radiation field should be increased to reduce the fluctuation of the readings. See NIST Technical Note 2073 for additional guidance (see Bibliography). The COV for the nominal mean reading shall be less than or equal to 12 % for measurements with sources.

For measurements without sources (i.e., at the level of background radiation), the BRD 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). Readings are expected to have large fluctuations (COV > 12 %).

The bibliography contains a list of several publications for additional information regarding statistical processes associated with radiation measurement.

4.5 Background radiation during testing

Testing shall be performed in a controlled area having a radiation background as defined in Table 1.

4.6 Radiation sources

For alarm tests, ^{241}Am, ^{137}Cs, and ^{60}Co are used to provide a fluence rate of 4 photons•s^{-1}•cm^{-2} (-0 %, +5 %) at the reference point of the BRD. The fluence rate shall be determined for the gamma-ray energies listed in Table 3. The ambient dose equivalent rate shall be determined using a photon cut-off energy of 40 keV. Annex A provides information for determination of fluence rate.

For identification tests, a fluence rate of 1,5 photons•s^{-1}•cm^{-2} (-0 %, +5 %) at the reference point of the BRD shall be emitted from DU, HEU, WGPu, ^{137}Cs, ^{60}Co, ^{67}Ga, ^{131}I, ^{99m}Tc, and ^{201}Tl. The medical radionuclides (^{99m}Tc, ^{67}Ga, ^{131}I, and ^{201}Tl) shall be surrounded by 8 cm of polymethyl methacrylate (PMMA) for test purposes to represent in-vivo conditions, for these sources the fluence rate is measured outside the PMMA. The fluence rate shall be determined for the gamma-ray energies listed in Table 3.

^{252}Cf or ^{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 high-density polyethylene (HDPE) moderator (density between 0,93 g•cm^{-3} and 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 not larger than 3 cm in diameter and length. The source shall be positioned at the centre of the cavity.

NOTE Additional information about neutron radiation fields can be found in ISO 8529-1:2021. Additional information can be found in R. Radev *et al.* in Bibliography.

Sources used for testing shall be checked for gamma-ray emitting impurities using a high purity germanium detector (HPGe). The spectra shall be recorded. Identification of impurities is acceptable.

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

For SNM and DU sources, different masses, shapes, and forms may be used for testing as long as the required fluence rate is obtained. For this document, HEU has an enrichment that is ≥90 % ^{235}U, DU has a ^{235}U abundance of 0,2 % to 0,4 %, and WGPu has a composition of ≤6,5 % ^{240}Pu and >93 % ^{239}Pu. The WGPu source may need to be shielded (e.g., with copper alloy ASTM B152) to reduce the measured emissions at 60 keV from ^{241}Am. 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. For example, if the emission rate for the 375 keV line is 100 s^{-1} then the emission rate for the 60 keV ^{241}Am line should not exceed 1 000 s^{-1}.

NOTE 1 The factor 10 was determined from source material measurements.

NOTE 2 Additional information about the use of SNM sources for testing can be found in IEC TR 62971.

4.8 BRD set up

The BRD should be set up based on the manufacturer’s recommendations including background update mode, if applicable. Once set up for testing, no changes should be made that could affect the overall response of the BRD.

When performing the radiological tests in Clause 6, the BRD shall be configured and oriented as it would be used. This is achieved by using a phantom to represent the human upper torso. The phantom shall be made of PMMA having dimensions of 40 cm wide, 60 cm high and 15 cm thick, see Figure 2.

The BRD shall be placed on a stand, table, or fixture made of a material that does not have a large hydrogen content (e.g., foam, plastic, wood). It is recommended to use materials such as aluminium to prevent possible additional moderation of the neutron source.

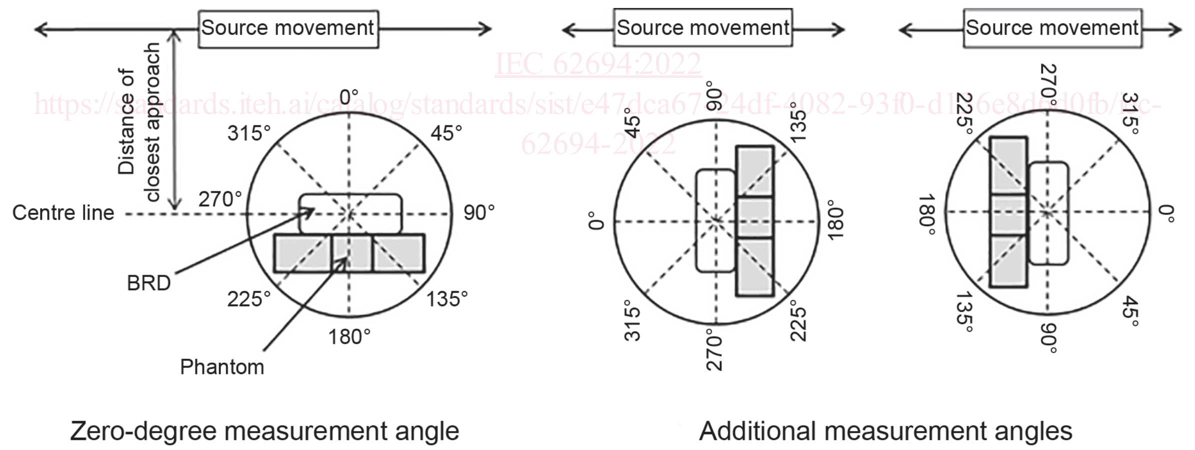
The reference point of the BRD should be identified by the manufacturer. If not provided, the reference point is the intersection of three mutually orthogonal lines that go through the center of the length, width, and thickness of the BRD (see Figure 1 and Figure 2). The refence point of the BRD shall be placed on the center of the phantom (placed at 30 cm from the bottom of the phantom).

For static and dynamic tests described in Clause 6, the reference point of the BRD shall be positioned at least 1,2 m from the floor or ground surface. The centreline of the source shall be at the same height as the reference point of the BRD.

For static tests, the distance between the source and the reference point of the BRD shall be between 1 m and 3 m, unless otherwise stated.

For dynamic tests, the distance of closest approach between the gamma sources and the reference point of the BRD shall be between 1 m and 3 m, unless otherwise stated.

When performing the tests in Clauses 7, 8, and 9, the BRD shall not be placed on a phantom.



The displayed source movement represents the test configuration at an angle of 0° while looking down on the phantom and BRD. When testing at 90° and 270° the source also moves in both directions.

Figure 1 – Diagram of the BRD testing angles and source movement directions