

American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

IEEE
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USA

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Secretariat

Institute of Electrical and Electronics Engineers, Inc.

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Abstract: Minimum performance specifications and testing methods for the evaluation of radiation portal monitors, also known as RPMs, are contained in this standard. These monitors are large-size permanently mounted-type instruments. These instruments are primarily designed for the detection of radioactive materials emitting gamma rays and neutrons. The specifications for general, radiological, environmental, electromagnetic and mechanical performance are given and the corresponding testing methods are described. The documentation to be provided by the manufacturer is listed as part of the requirements. A number of informative annexes that provide useful information and guidance in implementing this standard are also contained in this standard.

Keywords: ANSI N42.35, documentation, gamma-rays, information and guidance, neutrons, performance specifications and testing, permanently mounted, radiation, radiation detection, radiation detection instruments, radiation portal monitor, radioactive material

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Introduction

This introduction is not part of ANSI N42.35-2016, American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security.

This standard is the responsibility of the Accredited American Standards Committee on Radiation Instrumentation, N42. The standard was approved on N42 letter ballot.

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1. Overview

1.1 Scope

This standard establishes the performance requirements and provides the testing and evaluation criteria for installed radiation portal monitors (RPMs) that detect photon- and neutron-emitting radioactive substances by monitoring people, packages, containers, and vehicles.

Performance requirements for portal monitors with radionuclide identification capabilities are addressed by the ANSI N42.38 standard [B19]. Performance requirements for mobile and transportable systems are addressed by the ANSI N42.43 standard [B20].¹

1.2 Purpose

The purpose of this standard is to establish the baseline performance requirements and associated test methods for RPMs used to detect radioactive material. End users may have special applications or needs which are not addressed in this standard, such as challenging weather conditions, estimation of background suppression and/or masking and shielding configurations. Additional testing may be required to address

¹ The numbers in brackets correspond to those of the bibliography in Annex A.

these additional needs. RPMs with the ability to discriminate against naturally occurring radioactive materials (NORM) based on the measured radiation (e.g., limited spectral analysis and/or energy analysis capabilities) are addressed in this standard.

2. References

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Users of this standard should note that standards referenced herein may not fulfill the legal requirements and practices in all states, countries, or jurisdictions. Care should be taken to ensure regulatory compliance.

Additional references that are not indispensable for the application of this document are provided in the bibliography (see Annex A).

ANSI N42.42, American National Standard Data Format for Radiation Detectors Used for Homeland Security.^{2, 3}

IEC 60529, Degrees of protection provided by enclosures (IP Code).⁴

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

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

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁵

alarm: An audible, visual, or other signal activated when the instrument reading or response exceeds a preset value or falls outside of a preset range.

coefficient of variation, V : Ratio of the standard deviation s to the arithmetic mean $\bar{x}$ of a set of n measurements, x_i , given by the following equation:

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

² The ANSI N42.42 schema can be obtained from <http://www.nist.gov/pml/div682/grp04/n42.cfm>.

³ The ANSI N42 publications included in this clause are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

⁴ IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch/>). IEC publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

⁵ *IEEE Standards Dictionary Online* is available at: <http://ieeexplore.ieee.org/xpls/dictionary.jsp>.

coverage factor: Numerical factor (k) used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty.

detection assembly: Enclosure of the installed radiation portal monitor system that contains the detectors and associated electronic devices.

detection zone: The region either located between opposing detection assemblies or adjacent to a detection assembly over which a source can be detected.

NOTE—Annex B shows a diagram of the detection zone.⁶

detector: A device or component designed to produce a quantifiable response to ionizing radiation normally measured electronically.

energy analysis: Analysis based on the distribution of energies deposited in a detector from photon events.

evaluation distances: The distance between an evaluation test source and the exterior face(s) of the portal monitor unit(s), which corresponds to the surface of the detection assembly, during a trial.

exposure rate: The measure of ionization produced in air by x-ray or gamma-ray radiation.

NOTE—The special unit of exposure rate is the Roentgen per hour, abbreviated in this standard as R/h.

false alarm: Alarm not caused by a radioactive source under the specified background conditions.

indication: Displayed signal from the instrument to the user conveying information such as scale or decade, status, malfunction or other critical information.

influence quantity: Quantity that may have a bearing on the result of a measurement without being the subject of the measurement.

innocent alarm: An alarm resulting from an actual increase in radiation level, but for reasons that are not due to the detection of radioactive materials of interest.

NOTE—An innocent alarm is also called a nuisance alarm.

instrument: A complete system consisting of one or more assemblies designed to quantify one or more characteristics of ionizing radiation or radioactive material.

manufacturer: Includes the designer of the equipment.

monitoring: Means provided to continuously indicate the state or condition of a system or assembly.

NOTE—Monitoring may also be used for the real time measurement of radioactivity or radiation levels.

occupancy: When the detection zone is occupied with an object (e.g., person, vehicle, package) that is being monitored.

over-range response: The response of an instrument when exposed to radiation intensities greater than the maximum level at which the instrument meets the stated accuracy.

⁶ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

portal monitor: Radiation detection system that measures radiation intensity, compares it to alarm criteria, and produces an alarm if the measured radiation intensity exceeds the criteria when monitored material passes through the detection zone.

purchaser: Includes the user of the equipment.

radioactive material: Radioactive material includes both special nuclear and other radioactive material, unless otherwise specifically noted.

range: All values lying between the lower and upper detection limits.

reading: The indicated or displayed value of the readout.

readout: The portion of the instrument that provides a visual display of the response of the instrument or the displayed value, with units, displayed and/or recorded by the instrument as a result of the instrument's response to some influence quantity.

reference point of an instrument: Physical mark, or marks, on the outside of an instrument used to position it at a point where the conventionally true value of a quantity is to be measured, unless the position is clearly identifiable from the construction of the instrument.

reference point of the detection zone: The reference point of the detection zone is that point that is at the center of the detection zone in both axes (horizontal and vertical) at a distance from the detection assembly based on the monitor type given by the evaluation distance. The z-axis or depth position is determined based on the width (related to object flow) of the detection assembly.

reference position of an assembly: The position that is used to improve reproducible positioning of sources when determining the performance of the equipment.

NOTE—The reference position of a detection assembly is located at the centered height and width of the entire detection assembly or it is a physical mark on the detection assembly.

relative error [ϵ_{REL} (%)]: The difference between an instrument's reading, M , and the conventionally true value, CTV , of the quantity being measured divided by the conventionally true value multiplied by 100.

$$\epsilon_{REL} (\%) = [(M - CTV) / (CTV)] \times 100$$

remote station: Monitoring station that is not physically collocated with the radiation portal monitor (RPM).

NOTE—The personal computer used to control the RPM is considered to be part of RPM, it is not part of the remote station.

response time: The time interval required for the instrument reading to change from 10% to 90% of the final reading or vice versa, following a step change in the radiation field at the detector.

sample variance (s^2): A 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, n .

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

sigma: Measure of statistical significance expressed in units of standard deviation.

NOTE—The critical level or alarm threshold of an RPM can be set in sigma units (sigma value based on gamma and neutron background readings).

standard deviation: The positive square root of the sample variance.

standard test conditions: The range of values of a set of influence quantities under which a calibration or a measurement of response is carried out.

standard test sources: A set of calibrated sources required to perform evaluation and periodic operational testing.

test: A procedure whereby the instrument, circuit, or component is evaluated.

type test: Initial test of two or more production instruments made to a specific design to show that the design meets defined specifications.

uncertainty: The estimated bounds of the deviation from the conventionally true value, generally expressed as a percent of the mean, ordinarily taken as the square root of the sum of the square of two components: 1) Random errors that are evaluated by statistical means; and 2) systematic errors that are evaluated by other means.

3.2 Acronyms and abbreviations

ac	alternating current
ESD	electrostatic discharge
GADRAS	gamma detector response and analysis software
HDPE	high density polyethylene
HPGe	high purity germanium
IP	ingress protection
LANL	Los Alamos National Laboratory
NIST	National Institute of Standards and Technology
NORM	naturally occurring radioactive material
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
POV	privately owned vehicle
RF	radio frequency
RH	relative humidity
RPM	radiation portal monitor
US	United States

4. General considerations

4.1 Evaluation of radiation portal monitors

Testing is conducted under a set of conditions to determine if an RPM meets the requirements of this standard.

Unless otherwise specified in an individual step, all tests enumerated in this standard are to be considered type tests. Certain tests may be considered acceptance tests by agreement between the customer and manufacturer.

All test results shall be documented.

4.2 Meeting performance specifications

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

4.3 Units and uncertainties

Unless otherwise stated, the uncertainties for any measurable quantity (e.g., temperature, humidity, electromagnetic field, speed, source encapsulation) should not exceed 15%. The radiation field or exposure rate uncertainty should not exceed $\pm 20\%$; except for the radiation background measurements, for which the uncertainty may be larger than the value stated here. Unless otherwise stated, the uncertainties are specified with a coverage factor (k) of 1.

Radiation fields may be determined through measurements or calculations. Measurement of the radiation field shall be performed using devices with a known energy response function and with a NIST traceable (or equivalent recognized organizations) exposure rate calibration. When radiation fields are determined through calculations, the technique and reference data (e.g., photon energies, emission probabilities, attenuation coefficients, absorption coefficients) used to determine the field and associated uncertainty shall be described in the test record. Measurement of all influence quantity (i.e., environmental, electromagnetic, mechanical) values shall be made using equipment traceable to NIST or equivalent organizations.

For the purposes of this standard, the radiological units of exposure rate [expressed in Roentgen per hour (R/h)] shall be used for x-ray and gamma-ray radiation. Devices used to measure gamma radiation fields shall measure exposure rate. It is not possible to perform measurements of exposure rate using a device that measures ambient dose equivalent rate unless conversion coefficients are applied (see ISO/IEC 4037-3 [B49]).

4.4 Special word usage

The following word usage applies:

- The word “shall” signifies a mandatory requirement (where appropriate, a qualifying statement is included to indicate that there may be an allowable exception).
- The word “should” signifies a recommended specification or method.
- The word “may” signifies an acceptable method or an example of good practice.

4.5 Standard test conditions

Except where otherwise specified, the tests in this standard should be performed under the standard test conditions given in Table 1.

For those tests intended to determine the effects of variations in the influence quantities (tests in Clause 7, Clause 8, and Clause 9), all other influence quantities shall be maintained within the limits of the standard test conditions, unless otherwise specified in the applicable test procedure.

Table 1—Reference and standard test conditions

Influence quantity	Standard test conditions
Ambient temperature	18 °C to 25 °C
Relative humidity (RH)	Less than 75%
Atmospheric pressure	70–106.6 kPa (525–800 mm of mercury at 0 °C)
Gamma radiation background (for tests in Clause 6)	5–10 $\mu\text{R/h}$
Gamma radiation background (for tests in Clauses 7, 8, and 9)	$\leq 10 \mu\text{R/h}$
Neutron background	$\leq 200 \text{ neutrons/s/m}^2$
Electromagnetic field of external origin	Controlled natural conditions (natural conditions without the presence of man-made generators)
Magnetic induction of external origin	Controlled natural conditions (natural conditions without the presence of man-made generators)
NOTE 1—The gamma-ray and neutron background values used for testing are based on background variations observed in the environment where the RPMs are deployed for homeland security applications in the US. See Annex F. NOTE 2—The gamma radiation background for tests in Clause 7, Clause 8, and Clause 9 can be lower due potential shielding provided by the testing equipment. For these tests, only the relative RPM response is evaluated.	

4.6 Statistical fluctuations

For tests involving the use of radioactive sources to verify susceptibility to an environmental, electromagnetic, or mechanical condition (Clause 7, Clause 8, and Clause 9), the exposure rate produced to verify the RPM response shall be adjusted to reduce the magnitude of the statistical fluctuations.

If the magnitude of the statistical fluctuations of the RPM indication 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 equal or greater than 8%), then the exposure rate should be increased to reduce the mean value of such readings (to ensure that the mean value of such readings may be estimated with sufficient accuracy to demonstrate compliance with the test in question). If the exposure cannot be increased to meet the required coefficient of variation then the number of readings should be increased as described in Table F.1 (see Annex F.7). The coefficient of variation (V , expressed in percentage) for each nominal mean reading should be less than or equal to 8%.

For measurements without sources (at background level), attaining a coefficient of variation to meet this requirement may not be possible. In these cases, the RPM is observed 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. Therefore, testing without sources can be performed even when the coefficient of variation is larger than 8%.

4.7 Background radiation during testing

Testing shall be performed in an area with a known gamma-ray and neutron background environment that has only natural variation (i.e., no radioactive sources present). The gamma-ray and neutron background measurement shall be recorded with its associated uncertainty. This measurement does not need to meet the uncertainty requirement in 4.3.

The gamma-ray background intensity shall be measured using a pressurized ion chamber or similar environmental radiation measurement device. A high purity germanium (HPGe) detector should be used to obtain a background spectrum to confirm that only background radionuclides (e.g., ^{40}K , ^{232}Th series, ^{238}U series) are present in the testing area. For the neutron background, unless it can be assured that no neutron sources are in the area, the neutron background level shall be measured using a neutron counter or similar device that has the ability to measure environmental level neutron radiation levels (e.g., integrating counter or dosimeter).

When performing tests with or without radiation sources, actions shall be taken to confirm that no additional radiation sources are present that can alter the ambient background. For example, when performing repetitive tasks, the radiation source shall be shielded at the end of the testing stand or sources shall be at a distance so the background is unaffected between each pass or occupancy. The background shall be unaffected in the test area or area surrounding the detection assembly.

4.8 RPM setup

The RPM mounting distance for testing is described in 4.9.

The RPM shall be set up based on the manufacturer's specifications. For the radiological tests, no additional shielding shall be applied (i.e., shielding and/or moderation), except for that shielding which is a permanent feature of the RPM or as required for a specific test. The operational settings (e.g., thresholds, operational mode) shall be recorded. Once set up for testing, no changes shall be made that could affect the overall response of the RPM. In particular, no changes shall be made to the RPM settings and/or thresholds between the false alarm test and the detector gamma-ray and neutron response tests.

The electrical, electromagnetic, mechanical, and environmental tests may be performed with the smallest structure that the manufacturer requires for operation (e.g., one panel plus cooling system and necessary cabling) instead of testing the entire system.

4.9 Evaluation distances and speeds

The setup or evaluation distances for different applications are given in Table 2; these distances are measured from the external face of the RPM detection assembly (or panel).

The distances, occupancy times, and passage or transit speed are listed in Table 2; these values are for evaluation purposes only. Other distances may be used in deployment configurations. If installation requires distances other than those tested, further testing may be required to determine that performance requirements are met.

4.10 Radiation sources

Sources used for testing the radiation portal monitors shall be traceable to NIST (or other equivalent primary laboratory) and shall have appropriate documentation to demonstrate the traceability chain (see ANSI N42.22 [B1] and ANSI N42.23 [B2]). Source activities required for testing are listed in Table 3; Annex F provides additional information.

Table 2—Evaluation distances and testing speeds for different RPM classifications

RPM classification	Distance between detection assemblies measured from the external face of the RPM detection assembly ^a	Source to detector assembly surface distance ^a	Source speed ^b	Occupancy time ^{a, b}
Double-sided rail vehicle RPMs	6 m	Centered between detection assemblies	2.2 m/s	5 s
Double-sided vehicle RPMs (includes containerized cargo)	5 m	Centered between detection assemblies	2.2 m/s	5 s
Single-sided pedestrian RPMs	N/A	1 m	1.2 m/s	1 s
Single-sided package RPMs	N/A	1 m	1.2 m/s	1 s
Fixed-dimension multiple-sided pedestrian or package RPMs	Defined by construction	Centered between detection assemblies	1.2 m/s	1 s
Double-sided pedestrian RPMs	1 m	Centered between detection assemblies	1.2 m/s	1 s
Double-sided package RPMs	1 m	Centered between detection assemblies	1.2 m/s	1 s

^a The stated values have a tolerance of $\pm 10\%$.

^b Applies to the false alarm test only.

Table 3—Gamma source activities and neutron source emission rate

Radionuclide	Source activity/Emission rate	Main photon energies (keV)
²⁴¹ Am	47 μ Ci (1.74 MBq)	59.5
⁵⁷ Co	5 μ Ci (185 kBq)	122.1
¹³³ Ba	14 μ Ci (518 kBq)	356.0
¹³⁷ Cs	16 μ Ci (592 kBq)	661.7
⁶⁰ Co	7 μ Ci (259 kBq)	1173.2 + 1332.5
²³² Th	14 μ Ci (518 kBq)	238.6
²²⁶ Ra	8 μ Ci (296 kBq)	609.3
Neutron (²⁵² Cf)	2×10^4 neutrons/s	N/A

NOTE 1—The actual activity of each gamma source at the time of testing shall be within (-20% , $+10\%$) of the value shown in this table. The uncertainty in the actual activity value shall be less than or equal to $\pm 5\%$ (1σ) for the gamma-ray sources. The uncertainty in the neutron emission rate shall be $\pm 10\%$ (1σ) for the ²⁵²Cf. The actual neutron emission rate of the source at the time of testing shall be within $\pm 20\%$ of the value shown in this table.

NOTE 2—The unmoderated neutron source should be encapsulated in 1 cm steel and 0.5 cm lead.

NOTE 3—Units: 1 μ Ci = 37 000 Bq.

NOTE 4—These activity levels are for testing only and are not indicative of the alarm set point or overall sensitivity of the RPM system, which are established based on the ambient background and acceptable false alarm rate.

NOTE 5—Gamma-ray source activities are based on encapsulation in 0.25 mm wall thickness stainless steel.

NOTE 6—The ²³²Th and ²²⁶Ra are in equilibrium with its progeny.