

American National Standard for Performance Criteria for Spectroscopy-Based Portal Monitors Used in Homeland Security

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

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American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

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Abstract: The performance requirements for spectroscopy-based portal monitors are described in this standard. The requirements stated are based on portal monitors used in support of efforts associated with the U.S. Department of Homeland Security.

Keywords: ANSI N42.38, portal monitor, spectrometric, spectroscopy

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Introduction

This introduction is not part of ANSI N42.38-2015, American National Standard for Performance Criteria for Spectroscopy-Based Portal Monitors Used for 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 specifies the operational and performance requirements for spectroscopy-based portal monitors (SRPMs) used in homeland security applications. SRPMs have the ability to detect radioactivity and identify radionuclides that may be present in or on persons, vehicles, or containers through the use of gamma spectroscopy techniques.

Operational requirements established by this standard include radiation detection and radionuclide identification, and those requirements associated with the expected electrical, mechanical, and environmental conditions when a SRPM is deployed. The test methods described in this standard provide a means to ensure that a SRPM meets the requirements stated. Successful completion of the tests described in this standard should not be construed as an ability to successfully detect and identify all radionuclides in all environments.

This standard does not address portal monitors that may have the ability to reduce the effects caused by the presence of naturally occurring radioactive material (NORM) without the ability to identify specific radionuclides. Monitors with this capability are addressed by ANSI N42.35.

1.2 Purpose

The purpose of this standard is to specify the performance criteria and test methods for SRPMs used for homeland security. Testing is conducted under a set of conditions to determine if an SRPM meets the requirements of this standard. Special applications, which could include an SRPM's operation under weather conditions not addressed by this standard, shall require additional testing. Detection needs not addressed by this standard shall also require additional testing, e.g., estimation of the background depression due to vehicle presence, masking, or shielding configurations.

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

2. Normative 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.

ANSI C63.4, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.¹

ANSI N42.22, American National Standard—Traceability of Radioactive Sources to the National Institute of Standards and Technology (NIST) and Associated Instrument Quality Control.²

ANSI N42.23, American National Standard Measurement and Associated Instrumentation Quality Assurance for Radioassay Laboratories.

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

ANSI/TIA-232-F-1997, Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.⁴

ANSI/TIA/EIA-485-A-1998, Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems.

FCC Rules, U.S. Code of Federal Regulations, Title 47 Part 15 (47 CFR 15), Telecommunication—Radio Frequency Devices.⁵

IAEA Safety Guide No. RS-G-1.9, Categorization of Radioactive Sources.⁶

¹ ANSI C63 and ANSI N42 publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

² See footnote 1.

³ The ANSI N42.42 schema can be obtained from <http://www.nist.gov/pml/div682/grp04/n42.cfm>.

⁴ TIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

⁵ CFR publications are available from the U.S. Government Publishing Office, P.O. Box 979050, St. Louis, MO 63197-9000, USA (<http://www.ecfr.gov/>).

- IEC 60050, Chapter 395, International Electrotechnical Vocabulary.⁷
- IEC 60068-1, Environmental Testing—Part 1: General and Guidance.
- IEC 60068-2-11, Basic environmental testing procedures—Part 2-11: Test Ka—Salt mist.
- IEC 60068-2-18, Environmental Testing—Part 2-18: Tests—Test R and Guidance: Water.
- IEC 60068-2-75, Environmental Testing—Part 2-75: Tests—Test Eh: Hammer Tests.
- IEC 60529, Degrees of Protection Provided by Enclosures (IP Code).
- IEC 60721-4-4, Classification of Environmental Conditions—Part 4-4: Guidance for the Correlation and Transformation of Environmental Condition Classes of IEC 60721-3 to the Environmental Tests of IEC 60068—Stationary Use at Non-Weatherprotected Locations.
- IEC 61000-4-1, Electromagnetic Compatibility (EMC)—Part 4-1: Testing and Measurement Techniques—Overview of IEC 61000-4 Series.
- IEC 61000-4-2, Electromagnetic Compatibility (EMC)—Part 4-2: Testing and Measurement Techniques—Electrostatic Discharge Immunity Test.
- IEC 61000-4-3, Electromagnetic Compatibility (EMC)—Part 4-3: Testing and Measurement Techniques—Radiated, Radio-Frequency, Electromagnetic Field Immunity Test.
- IEC 61000-4-4, Electromagnetic Compatibility (EMC)—Part 4-4: Testing and Measurement Techniques—Electrical Fast Transient/Burst Immunity Test.
- IEC 61000-4-5, Electromagnetic Compatibility (EMC)—Part 4-5: Testing and Measurement Techniques—Surge 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.
- IEC 61000-4-8, Electromagnetic Compatibility (EMC)—Part 4-8: Testing and Measurement Techniques—Power Frequency Magnetic Field Immunity Test.
- IEC 61000-4-12, Electromagnetic Compatibility (EMC)—Part 4-12: Testing and Measurement Techniques—Ring Wave Immunity Test.
- IEC 61000-4-14, Electromagnetic Compatibility (EMC)—Part 4-14: Testing and Measurement Techniques—Voltage Fluctuation Immunity Test for Equipment With Current Not Exceeding 16 A per Phase.
- IEC 61000-4-28, Electromagnetic Compatibility (EMC)—Part 4-28: Testing and Measurement Techniques—Variation of Power Frequency, Immunity Test for Equipment With Input Current Not Exceeding 16 A per Phase.
- IEC 61455:1995 (withdrawn), Nuclear Instrumentation—MCA Histogram Data Interchange Format for Nuclear Spectroscopy.⁸

⁶ IAEA publications are available from the International Atomic Energy Agency, P.O. Box 100, Wagramer Strasse 5, A-1400 Vienna, Austria (<http://www.iaea.org/>).

⁷ IEC publications are available from the International Electrotechnical Commission, Case Postale 131, 3 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

Manual for Railway Engineering, American Railway Engineering and Maintenance-of-Way Association, Mira Digital Publishing, Inc., 2015.⁹

NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum).¹⁰

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. *The IEEE Standards Definition Database* should be consulted for terms not defined in this clause.¹¹

acceptance test: Evaluation or measurement of performance characteristics to verify that certain stated specifications and contractual requirements are met.

accuracy: The degree of agreement between the instrument reading and the conventionally true value of the quantity being measured.

adjust: To alter the reading of an instrument by means of a built-in variable (hardware or software) control.

alarm: An audible, visual, or other signal activated when the instrument reading, response, or identification result exceeds a preset value, falls outside of a preset range, or indicates the presence of a radionuclide of interest, respectively.

calibration: A set of operations under specified conditions that establishes the relationship between values indicated by a measuring instrument or measuring system and the conventionally true values of the quantity or variable being measured.

category: A subdivision of radionuclides. Examples include, but are not limited to, special nuclear material (SNM), medical, industrial, and naturally occurring radioactive material (NORM).

check source: A not-necessarily calibrated radiation source that is used to confirm the continuing functionality of an instrument.

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:

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

conventionally true value (CTV): The commonly accepted best estimate of the value of that quantity.

NOTE—This estimate and the associated uncertainty will preferably be determined by a national or transfer standard, or by a reference instrument that has been calibrated against a national or transfer standard, or by a measurement quality assurance interaction with the National Institute of Standards and Technology (NIST) or an accredited organization.¹²

⁸ IEC 61455:1995 has been withdrawn; however, copies are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

⁹ AREMA publications are available from AREMA, 10003 Derekwod Lane, Suite 210, Lanham, MD 20706-4362, USA (<http://www.arena.org>).

¹⁰ NEMA publications are available from the National Electrical Manufacturers Association, 6300 Interfirst Drive, Ann Arbor, MI, 48108, USA (<http://www.nema.org/>).

¹¹ *IEEE Standards Definition Database* is available at: <http://dictionary.ieee.org>.

decade: A range of values for which the upper value is ten times greater than the lower value.

detection assembly: The monitor enclosure that includes the detector, the associated electronics and the mounting components.

NOTE—The lower detection limit is the minimum statistically quantifiable instrument response or reading. The upper detection limit is the maximum level at which the instrument meets the required accuracy.

detection zone: The region that is either located between opposing detection assemblies or adjacent to a detection assembly over which the detection requirements are satisfied.

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

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

effective range of measurement: Range of measurements within which the requirements of this standard are met.

efficiency: The number of counts in a region corresponding to the energy of the emitted gamma rays minus the background counts in the same region registered by the detector per unit time divided by the number of photons of that energy originating from the radioactive source that is being measured during the same unit of time.

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

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

false alarm: An indication of the presence of a radioactive source or increase in the measured radiation level when that radioactive source or increase is not present.

false identification: An identification of a radionuclide that is not present.

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.

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

manufacturer: The organization, typically including the designer or developer, that produces the equipment and software.

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

NOTE—The term may also be used for the real-time measurement of radioactivity or exposure rate.

occupancy: When an object (person, vehicle, package, etc.) being monitored is in the detection zone.

over-range response: The response of an instrument when exposed to radiation intensities that are greater than the upper measurement limit. *Syn:* **overload response.**

¹² 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: A radiation measurement device designed to detect changes in the measured exposure rate as an object passes through or is placed in an area that is adjacent to a radiation detection assembly or assemblies.

purchaser: The organization, including the user, that buys the equipment.

radioactive material: A material of which one or more constituents' exhibit radioactivity. In this standard, radioactive material includes special nuclear material unless otherwise specifically noted.

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.

remote station: A computing system or subsystem used for data archiving, control, annunciation, printing, or other functions for portal monitor assemblies, typically located at a distance from the portal monitors.

response: Ratio of the instrument reading to the conventionally true value of the measured quantity.

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.

routine test: Test that applies to each independent instrument to ascertain compliance with specified criteria.

spectroscopy-based portal monitor (SRPM): A portal monitor that uses gamma spectroscopy techniques for the identification of radionuclides.

standard deviation: The square root of the 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.

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.

3.2 Acronyms and abbreviations

COV	coefficient of variation
DU	depleted uranium
EM	electromagnetic
ESD	electrostatic discharge
HDPE	high density polyethylene
HEU	highly enriched uranium
HPGe	high purity germanium
LEU	low enriched uranium
NORM	naturally occurring radioactive material
PMMA	polymethyl methacrylate
RF	radio frequency
RGPu	reactor grade plutonium

RH	relative humidity
SNM	special nuclear material
SRPM	spectroscopy-based portal monitor
WGPu	weapons grade plutonium

4. General

4.1 General considerations

All tests are to be considered as type tests unless otherwise specified in an individual step. If the manufacturer claims a broader range of operation (for example, an operating temperature range of $-40\text{ }^{\circ}\text{C}$ to $+60\text{ }^{\circ}\text{C}$) and the user requires this range, then additional testing and verification should be agreed upon between the manufacturer and purchaser. Certain tests may be considered as acceptance tests by agreement between the purchaser and manufacturer.

4.2 Standard test conditions

Except where otherwise specified, the tests in this standard shall be carried out under the standard test conditions shown in Table 1.

Table 1—Standard test conditions

Influence quantity	Standard test conditions (unless otherwise indicated by the manufacturer)
Ambient temperature	$18\text{ }^{\circ}\text{C}$ to $25\text{ }^{\circ}\text{C}$
Relative humidity (RH)	$\leq 75\%$ RH
Atmospheric pressure	70 kPa to 106.6 kPa (525 mm to 800 mm of mercury at $0\text{ }^{\circ}\text{C}$)
Electromagnetic field of external origin	Controlled, natural conditions
Magnetic induction of external origin	Controlled, natural conditions
Monitor controls	Setup for normal operation
Background exposure rate – gamma	$\leq 10\text{ }\mu\text{R/h}$
Neutron background	≤ 200 neutrons per second per sq. meter (see Note)
NOTE—The standard test conditions for neutron background are considerably higher than sea level.	

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

4.3 Units and uncertainties

The uncertainty of the radiation source activity should not exceed $\pm 10\%$ with a coverage factor (k) of 2 (95% confidence).

The source activity range shall be within $\pm 20\%$ of the nominal values listed in Table 4.

The uncertainties for all other measurable quantities [e.g., exposure rate, temperature, humidity, electromagnetic (EM) field] should not exceed $\pm 30\%$ with a coverage factor (k) of 2 (95% confidence). For the purposes of this standard, the radiological unit of exposure rate, R/h, is used. All other quantities are expressed in SI units.

4.4 Special word usage

The following word usage applies:

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

5. Design requirements

5.1 General characteristics

SRPMs shall detect changes in radiation levels and identify radionuclide(s) in or on objects, containers, vehicles, or pedestrians when the detected radiation meets or exceeds an alarm condition (exposure rate or identification result). Radiation measurement occurs as an object passes through the detection zone at the speed given in Table 2 or with an object static within the detection zone for the time given in Table 2 where the user may perform controlled analyses of the object (e.g., enters collection time and activates the measurement). The size of the detection zone is based on the classification of use. If an SRPM is used in two or more classifications, its associated detection zone shall be appropriate for each classification.

According to their intended use, SRPMs are classified as follows:

- Pedestrian
- Package (e.g., conveyor)
- Vehicle (including containerized cargo)
- Rail vehicle

5.1.1 Pedestrian

Pedestrian SRPMs shall provide a detection zone to ensure that people are monitored. Pedestrian SRPMs may use a single detection assembly (single-sided) or multiple opposing detection assemblies with or without detectors across the top and/or bottom part of the detection assembly. The distance between opposing detection assemblies, source to detection surface distance, dynamic testing speed, static measurement time, and detection zone bottom and top are stated in Table 2. If the distance between detection assemblies is fixed by the design of the SRPM, the center distance shall be used for testing.

Table 2—Setup and test parameters

Monitor type	Distance between detection assemblies measured from the face of each detection assembly ^a	Source to detection surface test distance ^a	Dynamic speed ^a	Measurement time for static testing	Detection zone bottom ^a	Detection zone top ^a
Single-sided pedestrian	N/A	1 m	1.2 m/s	30 s	0.1 m	2 m
Fixed dimension pedestrian	N/A	Centered between detection assemblies	1.2 m/s	30 s	0.1 m	2 m
Multiple-sided pedestrian	1 m	Centered between detection assemblies	1.2 m/s	30 s	0.1 m	2 m
Fixed dimension package monitors	N/A	Centered between detection assemblies	1.2 m/s	30 s	1 m ^b	0 m ^b
Multiple-sided or single-sided package monitors	1 m	Centered between detection assemblies or 1 m from the face of the detector	1.2 m/s	30 s	1 m ^b	0 m ^b
Multiple-sided small vehicle monitors (includes cars and vans)	3 m	Centered between detection assemblies	2.2 m/s (8 km/h)	60 s	0.2 m	2.5 m
Multiple-sided vehicle monitors (includes containerized cargo)	5 m	Centered between detection assemblies	2.2 m/s (8 km/h)	60 s	0.2 m	4.5 m ^c
Multiple-sided rail monitors	6.5 m	Centered between detection assemblies	2.2 m/s (8 km/h)	60 s	0.3 m	7 m

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

^b These systems are designed to monitor objects that pass through the detection zone on rollers or a conveyor. The bottom of the detection zone for testing purposes is the distance from the surface of the detection assembly to the top surface of the conveyor or roller assembly (1 m) on which an object is placed for monitoring. The top of the detection zone is the surface of the detection assembly. Testing could be performed by placing the source on the conveyor, roller assembly or a device that performs the same function (e.g., track). This is the reason for a 0 m distance since the source is on the surface. A different distance may be used when necessary based on the design and implementation of the system under test. The use of a different distance shall be stated in the test record.

^c For vehicle monitors designed to screen smaller vehicles (e.g., cars, vans), the detection zone may be from 0.2 m to 2.5 m above the ground.

5.1.2 Package (or conveyor SRPMs)

Package or conveyor SRPMs shall provide a detection zone to ensure that items moving through the detection zone are monitored. SRPMs may use a single detection assembly (single-sided) or multiple opposing detection assemblies, which may have detectors across the top and/or bottom part of the detection assembly (multi-sided).

As a minimum, the height of the detection zone shall be either one of the following:

- a) From the base surface to 1 m above the base surface (that surface which corresponds to the ground or conveyor bottom surface) for detectors mounted below the base surface.
- b) From the base surface to the face of the detection assembly for detectors mounted 1 m above the base surface.

The dynamic testing speed and static measurement time are listed in Table 2.

5.1.3 Vehicle (includes road-transported containers)

Vehicle SRPMs shall provide a detection zone to ensure that the entire vehicle is monitored during passage. The distance between opposing detection assemblies (see Annex B), source to detection surface distance, dynamic testing speed, static measurement time, and detection zone bottom and top are stated in Table 2. If the distance between detection assemblies is fixed by the design of the SRPM, the center distance shall be used for testing.

5.1.4 Rail vehicle (includes rail-transported containers)

Rail vehicle SRPMs shall provide a detection zone that ensures that the entire rail vehicle is monitored as it passes through the detection zone (dynamic measurements). The distance between opposing detection assemblies, source to detection surface distance, dynamic testing speed, static measurement time, and detection zone bottom and top are stated in Table 2. If the distance between detection assemblies is fixed by the design of the rail monitor, the center distance shall be used for testing. For test purposes, the ground surface should be considered as the top of the rail.

NOTE—Rail cars can significantly reduce the measured radiation response during an occupancy such that the response is less than the stored background response (baseline suppression). This effect could dynamically impact sensitivity. Tests for these effects are not included in this standard.

5.2 Physical configuration

Enclosure(s) provided for outdoor assemblies shall be designed to meet IP54 classification as designated in IEC 60529. Verification is performed in 7.3.

The detection assemblies for road and rail vehicle monitoring may be subjected to vibration. SRPMs and installation techniques (e.g., concrete pads, support brackets) shall be designed to prevent mechanical transients from interfering with the operation of the detection system. Installation techniques shall be described in the manufacturer-provided documentation.

5.3 Radiological configuration

5.3.1 Requirements

Requirements of the radiological configuration are as follows:

- a) The user shall have the ability to display or save a spectrum.
- b) The SRPM shall have the ability to internally store at least 1000 complete occupancy data files. For SRPMs that do not use occupancy sensors, the system shall have the ability to internally store 3 h of measurement data as defined in item c).
- c) Each measurement or occupancy data file shall meet ANSI N42.42 requirements and contain as a minimum the following information. [Several validation tools are available to verify compliance with the ANSI N42.42 standard (e.g., <https://secwww.jhuapl.edu/n42/Account/LogOn>).]
 - Manufacturer name
 - Instrument model
 - Serial number
 - Software version
 - Instrument class (i.e., SRPM)

- Gamma detector kind (e.g., NaI, GMT, PVT)
- Date and time of measurement
- Measured background radiation levels (i.e., count rate)
- Measured gamma-ray radiation level (i.e., count rate)
- Gamma-ray alarm indication
- Background spectrum
- Live time and real time for background spectrum
- Unprocessed measured spectrum (multiple spectra may be taken at, for example, 0.1 s intervals during an occupancy)
- Live time and real time for measured spectrum
- Energy calibration for each background and measured spectrum
- Radionuclide identification results
- Confidence indication, if provided

If the SRPM has neutron detection capabilities, the data file shall include the following information:

- Neutron detector kind (e.g., He-3, Li-Glass)
- Background neutron level (i.e., count rate)
- Measured neutron radiation levels (i.e., count rate)
- Neutron alarm indication

If occupancy and/or speed sensors are used, the data file shall include the following information:

- Occupancy sensor status
- Object speed
- Indication that the object stopped within the detection zone
- Sensor failure

- d) The SRPM shall have the ability to transfer each data file to an external device, such as a computer, at user-selectable intervals.
- e) The SRPM shall store background count rate and spectra and have the ability to transfer that information at user selectable intervals to an external device, such as a computer.
- f) The SRPM shall store photon and neutron count rate time-history data and have the ability to transfer that information at user selectable intervals to an external device, such as a computer.
- g) If a confidence indication is provided, the manufacturer shall describe its basis.
- h) The SRPM shall have the ability to perform identification measurements with a static object in the detection zone. This function shall be user selectable and does not supersede the requirements stated in 6.8. The recommended measurement time shall be stated by the manufacturer and should be less than or equal to the static measurement times listed in Table 2.

5.3.2 Test method

Each requirement is verified by review of the manual, data file review, and direct observation of the user display.

5.4 Indication and alarm features

5.4.1 Requirements

- a) The SRPM shall provide an indication of its operational status and alarm condition, shall be capable of transmitting these signals to remote stations, and shall be designed to permit verification of visual and audible warning indicators (e.g., light test) without the use of radiation sources.
- b) The user shall have the ability to select whether a status indication is visible at a location other than the user display (e.g., lamps or beacons at the detection assembly), and to select how an alarm resets either manually or automatically without user intervention.
- c) Once an alarm is activated, the SRPM shall have the ability to accumulate further alarms or measurement results until the alarm is acknowledged or reset.

5.4.2 Test method

- a) Verification shall include review of the manual, direct observation of the user display at the remote station, and performance of a test without the use of radiation sources.
- b) Verification shall be by performance of the stated requirement.
- c) Verify that further alarms or measurements take place while the system is in alarm.

5.5 Occupancy and speed sensors for vehicle SRPMs

5.5.1 Requirements

- a) Vehicle SRPMs shall have the ability to support occupancy sensors.
- b) If used, occupancy and speed sensors:
 - Shall be able to detect vehicle presence and speed
 - Should not count a single vehicle or object in the detection zone more than once
 - May have the ability to count a segmented vehicle (i.e., tractor/trailer) as one object
 - Should be capable of operating on a mix of traffic (e.g., cars, vans, pickup trucks, buses, cargo trucks, trains)
 - Should function under all environmental conditions stated in this standard
- c) Rail SRPMs should have the ability to approximate the location of an alarm from an individual railcar when monitoring multi-car trains.
- d) Function variables such as occupancy time and time between occupancies shall be user-selectable. Default values, based on the object being measured, shall be stated by the manufacturer.

5.5.2 Test method

- a) Verification shall be by review of the manual.
- b) Verification of the vehicle presence and speed requirement shall be by review of the manual and direct observation during transient testing.

NOTE—The testing process does not include a vehicle and therefore the speed measurement may not be correct.

- c) Verification shall be by review of the manual.
- d) Verification shall be by review of the manual and direct user action.

5.6 Markings

5.6.1 Requirement

Internal controls, when used, shall be identified and the identification shall match the information provided in the technical manual.

Exterior markings shall be limited to the manufacturer's unique serial number, voltage, and current requirements. If equipped with an outlet plug or receptacle, the connection shall meet minimum applicable municipal, state, federal, and international code requirements.

5.6.2 Test Method

- a) Inspect the internal controls and verify that the marking(s) match the description in the technical manuals.
- b) Inspect the exterior for markings and verify that only the serial number, voltage, and current requirements are shown.
- c) If equipped with an outlet plug or receptacle, verify that the minimum applicable municipal, state, federal, and international code requirements are met by checking for approval labels or stickers.

5.7 Protection of switches

5.7.1 Requirement

Switches and other controls should be designed to ensure that the SRPM can be operated properly while minimizing accidental switch operation. Controls and adjustments that affect calibration and alarm settings shall be designed so that access to them is limited to authorized personnel.

5.7.2 Test method

Verify that controls and adjustments are access controlled through either keyed panels and/or software passwords.

5.8 Effective range of measurement

5.8.1 Requirement

The effective photon energy response range shall be stated by the manufacturer and should be at least 40 keV to 3 MeV.

5.8.2 Test method

Review the manual and record the results.

5.9 Software and data analysis communications protocol

5.9.1 Requirement

SRPMs shall have the ability to transfer data to an external device, such as a computer. The transfer shall be based on a commonly available technology such as Ethernet, USB, RS-232, wireless (e.g., 802.11), or RS-485. Data security/encryption should be considered when using wireless data transfer techniques.

The transfer protocol and format shall be fully described in the technical manual and shall be freely distributable.

5.9.2 Test method

Verification is by manual review and direct transfer of data.

5.10 User interface

5.10.1 Visual indicators

Visual indicators shall be available for the following:

- Changes in operational status (e.g., occupied, alarm, monitoring background)
- Neutron alarm
- Special nuclear material (SNM) alarm
- Gamma alarm
- Radiological over range conditions (e.g., “over-range” or “high counts”)
- Radionuclide categorization, identification, and confidence indicator
- Detection without a radionuclide identified (e.g., “not identified”)
- Object present, if occupancy sensors are used
- Over speed (if speed is measured)
- System condition
- Operating mode

NOTE—Visual indications may include the use of colors that are indicative of the alarm type. For example, green for gamma alarms under the “danger” threshold and/or NORMS, red for gamma alarms to be verified because of the high activity level, and blue for neutron and/or SNM alarms (where different operational procedures are applied).

5.10.2 Warning indicators

The following warning indications shall be provided at the user interface as a minimum:

- Background changes during non-occupancies that can affect the overall sensitivity of the SRPM
- High or low detector count rate conditions indicative of a detector failure
- Energy stabilization invalid or not acceptable
- Occupancy sensor failure, if occupancy sensors are used

- Loss of line power
- Battery status
- System failure

5.10.3 User accessible indications and functions

The following information and control shall be provided for the trained user:

- View operational status
- View alarm indication
- Ability to reset alarms
- Ability to select transient or static scanning
- View identified radionuclide(s) (user selectable through advanced or supervisory access)
- Print alarm reports and summaries
- View history of alarms over a specified period
- Access to vehicle photo (if available)
- Access to radiation profiles (count-rate, time-history data)

5.10.4 Supervisory user accessible indications and functions

The following information and control shall be provided for the supervisory user through access controls or special commands that are described in the manufacturer provided technical manual:

- Access to and control of operating parameters (e.g., radionuclide library, alarm control, static measurement time, operational mode)
- Access to and control of data logging intervals
- Access to spectra
- Access to radionuclide identification results and control of basic indication function
- Access to occupancy data set (if occupancy sensors are used)
- Access to background radiation information
- Access to alarm selection criteria including the ability to select specific radionuclides
- Access to status indication criteria including the ability to set the exposure rate for activation of the high radiation indicator
- Access to energy and/or efficiency calibration information
- Access to time settings for static measurements

5.10.5 Verification

Each stated requirement shall be verified through manual review and direct observation using the appropriate access controls.

6. Radiation detection and indication performance requirements

6.1 General Test Method

This subclause provides information for test setup and execution.

6.1.1 Determination of test acceptance range and confidence interval

The tests described in Clause 7 (environmental performance requirements), Clause 8 (electrical and EM performance requirements), and Clause 9 (mechanical performance requirements) use an acceptance range based on the mean value and standard deviation derived from a series of measurements (e.g., count rate, dose rate). The range is typically $\pm 15\%$ adjusted to compensate for the standard deviation determined at nominal conditions. The following process is used to determine the acceptance range.

- a) Position the test source(s) as required and obtain ten (10) readings without moving the source(s). There should be a minimum of three (3) update intervals between each reading to ensure that each reading is independent.
- b) Calculate and record the mean response and experimental standard deviation for the series of readings.
- c) Use the following equation to establish the value “ l ”:

$$l = t_n \times s \div \sqrt{n}$$

where

- t_n is the two-sided Student’s t value for a 95% confidence interval (2.26 for a sample size of 10)
- s is the standard deviation of the series of measurements
- n is the number of measurements (10)

- d) Multiply the mean value by 15% (0.15) and then add the value “ l ” from step c).
- e) Add the value from step d) to the mean value to establish the upper limit and subtract the step d) value from the mean value to establish the lower limit. The upper and lower limits establish the acceptance range.

6.1.2 Test result analysis

6.1.2.1 Functionality

The results are acceptable if the SRPM performs as expected (e.g., no unexpected alarms or fault indications during the test).

6.1.2.2 Radiation response

- a) Calculate the mean and standard deviation from each series of readings and determine the confidence interval for each series of readings as described in 6.1.1.
- b) Calculate the value “ l ” from step c) of 6.1.1.
- c) Establish the confidence interval by adding and subtracting “ l ” from the mean.
- d) If the entire interval is within the acceptance range, the response results are acceptable. If the entire interval is outside of the acceptance range, the response results are unacceptable. If the interval is partially within the acceptance range, the response results may be considered conditionally acceptable.

6.1.2.3 Identification results

For Clause 7 (environmental performance requirements), Clause 8 (electrical and EM performance requirements), and Clause 9 (mechanical performance requirements), the identification results are acceptable if the number of complete and correct results (described in Annex C) at each test point from each series of identifications is the same as or better than the number of complete and correct results from the series of identifications performed prior to the test. For example, if the ten-trial results prior to a test are complete and correct in six out of ten trials, the complete and correct results at each test point shall be six or more to be considered acceptable.

6.1.3 System degradation from testing

It is recommended that whenever multiple tests are performed, initial pre-testing response values should be obtained and used to determine if there is a degradation of the SRPM as a result of the entire testing process. The initial pre-testing values may be obtained from each detector, each detector assembly, or the entire system based on the design of the SRPM and availability of response data. A position should be marked on the exterior of the detector assembly to indicate where each source is placed ensuring reproducibility. The system degradation test position(s) may also be used to obtain pre-test readings when performing individual tests.

The initial pre-testing readings are obtained using the following technique:

- a) Switch the SRPM on and allow it to start up in accordance with the manufacturer's instructions.
- b) Determine a location that could be marked as the initial pre-test gamma response position and place the ^{57}Co and ^{60}Co sources from Table 4 at that location. They may be in contact with the detector assembly case.
- c) With the sources in position, obtain a series of ten (10) gamma count rate readings and a spectrum.
- d) Remove the gamma sources.
- e) Determine a location that could be marked as the initial pre-test neutron response position and place the ^{252}Cf source assembly from 6.4.1 at that location.
- f) Record a series of ten (10) neutron count rate readings.
- g) Calculate and record the mean value and experimental standard for each series of readings.
- h) Calculate " I " as defined in step c) of 6.1.1. The value " I " is added and subtracted to each mean value to establish the upper and lower limits.

NOTE—This response range is for indication only and not for pass or fail determination.

- i) Record these pre-test ranges for use to determine if degradation took place.
- j) To determine if degradation may have occurred, place the same sources in the same positions established in step b) and step e) and perform the measurement process stated in step c), step d), step f), and step g).
- k) Compare the readings with the response range to determine if changes may have occurred.
- l) To determine if spectral changes have occurred, compare the peak positions from the initial performance of step c).

6.1.4 Background radiation during testing

CAUTION

When performing tests with radiation sources, actions shall be taken to ensure that when the SRPM is measuring background, no additional radiation is present that can alter the ambient background.

Testing shall be performed in an area with a nominal radiation (gamma-ray and neutron) background as defined in Table 1 that has only natural variation. When tests are performed, the gamma-ray background intensity shall be measured using a pressurized ion chamber or similar environmental radiation measurement device that is calibrated to provide gamma-ray exposure rate. A background spectrum shall also be acquired using an HPGe detector to ensure 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 dosimetry).

6.1.5 SRPM setup

An SRPM shall be set up based on the manufacturer's specifications. No additional shielding shall be applied, except for that shielding which is a permanent feature of the SRPM or as required for a specific test. The operational settings (e.g., libraries, thresholds, operational mode) shall be recorded. Once set up for testing, no changes shall be made that could affect the overall response of the SRPM.

6.1.6 Dynamic test method

Unless otherwise stated, one at a time, each source shall be passed horizontally through the bottom, middle, and top of the detection zone at the required speed as listed in Table 2 in a configuration that provides no shielding around the source other than that required for a specific test. The monitor's alarm shall be reset between each trial, if appropriate. There shall be a 10 s minimum delay between each trial with the source either positioned at a distance where it does not affect the background surrounding the SRPM or shielded during the delay.

6.1.7 Static test method

With the SRPM not measuring radiation (e.g., "in standby"), one at a time, place each source at the bottom, middle, and top of the detection zone. At each evaluation distance, initiate a measurement cycle for the specified static measurement time as shown in Table 2. The monitor's alarm shall be reset between each trial, if appropriate. Unless otherwise stated, there shall be a minimum 10 s delay between each trial. The source is not moved between trials to ensure that the source itself does not affect the measurement. This process replicates multiple measurements that may be performed with an object stationary or static within the detection zone.

6.1.8 Reference radiation

Unless otherwise stated, ^{137}Cs is the reference gamma radiation. All sources are listed in Table 4.

Source activities listed in Table 4 are based on photons emitted by a stainless steel (0.25 mm thick) encapsulated ^{137}Cs source (40 keV cut-off energy) that at 1 m produces a calculated exposure rate of 5 $\mu\text{R}/\text{h}$. The emission rate at the source is approximately 500 000 photons per second.

^{252}Cf is the reference source for neutron radiation. The source shall have a neutron emission rate of 20 000 n/s ($\pm 20\%$) and be surrounded by 4 cm of high density polyethylene (HDPE) for testing. The selection of 4 cm HDPE is based on measurements of the neutron spectrum with a ^{252}Cf source placed in a vehicle.

The test levels used for detection and identification purposes are not indicative of the alarm set point(s) or overall detection capability of a monitor.

6.1.9 SNM and other mass-based radiation sources

The fluence rate stated in Table 4 for the highly enriched uranium (HEU) is based on the emission rate from an HEU sphere with a mass of 237 g. The fluence rate for weapons grade plutonium (WGPu) is based on the emission rate from a WGPu sphere having a mass of 15 g and surrounded by 1 cm thick Fe. The depleted uranium (DU) fluence rate is based on the emission rate from a 2.5 kg plate with a surface area of approximately 400 cm² and a thickness of 0.3175 cm. Each fluence rate was determined at a source to detector distance of 1 m using the following information.

Material	Gamma line used for determination of fluence rate	Emission rate (gammas/s)	Fluence rate at 1 m (gammas/s/cm ²)
DU	1.001 keV	1.69×10^5	1.34
HEU	185.7 keV	1.81×10^5	1.44
WGPu	375.05 keV	5.01×10^4	0.40

Sources with different masses, shapes, and forms may also be used for testing. The DU source may be assembled from available standard reference materials (i.e., 100 cm² plates). A complete description of the source including mass, form, shape, and spectrum shall be obtained as part of the test record. For this standard, HEU has an enrichment that is $\geq 90\%$ ^{235}U , DU at 0.2% ^{235}U , and WGPu $\leq 6.5\%$ ^{240}Pu and $>93\%$ ^{239}Pu .

In order to gain consistency in testing, 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 no 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 cps, then the emission rate for the 60 keV ^{241}Am line should not exceed 1000 cps. Measurements shall be made using a characterized HPGe detector (i.e., with known full-energy-peak efficiency at the measurement distance and known energy calibration). The factor 10 was determined from source material measurements.

Use Equation (1) to determine the emission (or fluence) rates at the 60 keV and 375 keV.

$$R = \frac{\text{Area}_{\text{net}}}{T_{\text{Live}} \times \varepsilon(E)} \quad (1)$$

where

- Area_{net} is the net photo-peak area (in counts) of the gamma line of energy, E
- $\varepsilon(E)$ is the detector full-energy peak efficiency of the HPGe detector for the gamma-rays of energy, E
- T_{Live} is the live time of the measurement (expressed in seconds)

The measurement distance shall be the same as the one used to determine the full-energy peak efficiency of the HPGe detector.

6.2 False alarms/False identification

6.2.1 Requirement

The false alarm rate and false identification rate shall be less than or equal to 1 per 1000 occupancies.

NOTE—This requirement is for testing only. It contains two parts, false gross counting alarms, and false identifications that may be performed simultaneously. The requirement and associated test methods are not intended to verify the statistically based false alarm/identification rate as used by the monitor (typically 1:10 000). In order to verify the 1:10 000 rate, exceedingly long test times would be required. For that reason, 1000 trials have been selected as a reasonable number of trials with one (1) or less false alarms or false identifications as the acceptance criteria.

6.2.2 Test method

- a) Set up the SRPM as required by the manufacturer and in accordance with 6.1.5.
- b) If occupancy sensors are used, review the manufacturer-provided information to determine the process required to cause a 5 s occupancy for vehicle or rail systems or 1 s occupancy for pedestrian or conveyor monitors. The process may involve simultaneous blocking of two occupancy sensors, sequential blocking of sensors, or timed blocking of sensors.

NOTE—It is recommended that an automated track or similar device be used to perform this test. When used, the transit speed for the false alarm test is based on the 5 s occupancy period for vehicle and rail monitors or 1 s occupancy period requirement for pedestrian or conveyor monitors. If occupancy sensors are not used by the SRPM, the same automated process could be used to ensure that the number of trials and occupancy duration requirements are met.

- c) Perform a 10-trial gamma response test using ^{137}Cs at the middle test height and a 10-trial neutron response test at the middle test height in accordance with 6.3.2 and 6.4.2, respectively. Record the results.
- d) Remove the radiation sources from the testing area.
- e) Using the process determined in step b), perform 1000 occupancies with a 10 s minimum delay between each occupancy period.
- f) Observe the SRPM during the test and record any alarms or identifications that occur.
- g) When complete, repeat step c) as a means to ensure that the monitor remained functional during the test.
- h) The result is considered acceptable when no more than 1 gamma alarm, 1 neutron alarm, or 1 false identification occurs during the false alarm test.

6.3 Response to gamma radiation

6.3.1 Requirements

A gamma alarm shall be triggered when the detected gamma radiation level is greater than the alarm setting. This requirement is verified using ^{241}Am , ^{137}Cs , and ^{60}Co in individual tests.

NOTE—This test provides information about the gross counting capabilities of the system and is separate from the identification requirement that is described in 6.8 although identification results may be collected.

6.3.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.

- b) When the unit is operational, perform a single trial using the dynamic test method (see 6.1.6) by passing the ^{241}Am source from Table 4 horizontally through the bottom of the detection zone at the speed applicable to the monitor (Table 2). Record the result and reset the alarm after the trial when applicable.
- c) Repeat the process stated in step b) for a total of 60 trials. There shall be a 10 s minimum delay between each trial with the source either positioned at a distance where it does not affect the background at the SRPM location or shielded during the delay.
- d) Repeat steps b) and c) at the middle and top of the detection zone.
- e) Repeat steps b), c), and d) using the ^{137}Cs from Table 4.
- f) Repeat steps b), c), and b) using the ^{60}Co from Table 4.

NOTE—There are 60 trials per test height per source providing a total of 180 trials per source.

- g) The results per radionuclide are considered acceptable when the SRPM produces a gamma alarm in 177 out of 180 trials. This corresponds to a detection probability of approximately 0.96 at a 95% confidence level.

6.4 Response to neutron radiation

6.4.1 Requirement

A neutron alarm shall be triggered when the detected neutron radiation level is greater than the alarm setting. This requirement is verified using a ^{252}Cf source having a neutron emission rate of 20 000 n/s ($\pm 20\%$) that is surrounded by a 4 cm thick HDPE moderator.

6.4.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.
- b) When the SRPM is operational, perform a single trial using the dynamic test method (see 6.1.6) by passing the ^{252}Cf neutron source assembly horizontally through the bottom of the detection zone at the speed applicable to the monitor (Table 2). Record the result and reset the alarm after the trial when applicable.
- c) Repeat the process stated in step b) for a total of 60 trials. There shall be a 10 s minimum delay between each trial with the source either positioned at a distance where it does not affect the background at the SRPM location or shielded during the delay.
- d) Repeat steps b) and c) at the middle and top of the detection zone.

NOTE—There are 60 trials per test height per source providing a total of 180 trials.

- e) The results are considered acceptable when the SRPM produces a neutron alarm in 177 out of 180 trials. This corresponds to a detection probability of approximately 0.96 at a 95% confidence level.

6.5 Over-range

6.5.1 Requirement

If an SRPM is exposed to a gamma radiation field that is greater than the manufacturer-stated maximum when performing measurements, an alarm indicating, for example, “over-range” or “high counts” shall be activated and shall remain activated until the radiation field is reduced or the alarm is reset/acknowledged by the user.

If the alarm is reset/acknowledged by the user without the radiation field being reduced, a visual indication shall be provided indicating that the radiation field is still present and that the SRPM is not fully operational.

The time required to return to non-alarm condition after the radiation field is returned to background levels without any user interaction (other than acknowledging an audible alarm) shall not be greater than 1 min. If the maximum gamma radiation field is not provided by the manufacturer, testing is not possible.

NOTE—The test process used in 6.5.2 is also used in 6.6.2.

6.5.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.
- b) When the SRPM is operational, move a ^{137}Cs source into the detection zone at a distance needed to produce a radiation field that is 50% greater than the manufacturer-stated maximum value at the surface of the adjacent detection assembly and hold the position for a period of 1 min. The SRPM shall alarm and remain in alarm until the exposure rate is reduced to the pre-test level.
- c) Remove the radiation source and measure the time required for the SRPM to indicate that it is ready to function.
- d) To verify that the SRPM recovered after each overload exposure, perform a 10-trial simultaneous gamma and neutron alarm test using ^{137}Cs and ^{252}Cf at the middle test height following the guidance provided in 6.3.2 and 6.4.2, respectively.
- e) Repeat step b), step c), and step d) two (2) additional times for a total of three (3) trials.
- f) Repeat the test for each detection assembly, as necessary.
- g) The results are considered acceptable when the SRPM alarms in 29 of 30 trials (three 10-trial runs) for each source and recovers within 1 min after the ^{137}Cs source is removed in each of the three (3) successive trials.

6.6 Neutron indication in the presence of photons

6.6.1 Requirement

Gamma radiation at exposure rates up to 10 mR/h shall not trigger the neutron alarm. The monitor shall respond as required in 6.4.1 to the ^{252}Cf neutron source while simultaneously exposed to the 10 mR/h gamma field produced by ^{137}Cs .

NOTE—10 mR/h was selected based on typical exposure rates produced by medical sources that may be seen during use. ^{137}Cs was selected due to its photon energy being close to the maximum photon energy emission from commonly used medical radionuclides such as ^{131}I , $^{99\text{m}}\text{Tc}$, ^{201}Tl , and ^{67}Ga .

6.6.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.
- b) Gamma into neutron test (gamma rejection)
 - 1) Using ^{137}Cs , determine the distance that produces a radiation field of $10 \text{ mR/h} \pm 20\%$. The distance shall be at least 50 cm.
 - 2) Determine the source position relative to each detector assembly that contains a neutron detector based on the approximate center of the neutron detector within the detection assembly.

- 3) With the SRPM operational, move the ^{137}Cs source into the position determined in step b2) and record the neutron response.
 - 4) Repeat step b2) and step b3) for each detection assembly that contains a neutron detector.
- c) Neutron indication verification
- 1) Simultaneously move the ^{137}Cs source at the distance defined in step b2) and the ^{252}Cf source described in 6.4.1 at the test distance from Table 2 horizontally through the detection zone at the speed applicable to the monitor (Table 2).
 - 2) Repeat step c1) for a total of three (3) trials.
 - 3) Repeat step c1) and c2) for each detection assembly that contains a neutron detector.
- d) The results are acceptable if no neutron alarms are triggered when exposed to the ^{137}Cs field alone and if the neutron alarm activates as required while being exposed to the ^{252}Cf during exposure to the ^{137}Cs field.

6.7 Background effects

6.7.1 Requirement

An alarm shall be activated to indicate when the ambient radiation background has increased to a level that is too high for the monitor to operate as required. The indication shall be visual and audible and shall be different than monitoring alarms.

6.7.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.
- b) Set the dynamic test speed to 0.12 m/s for pedestrian and conveyor monitors or 0.22 m/s for vehicle monitors to mimic a slowly approaching source.
- c) Position the ^{137}Cs source from Table 4 at the middle test height at a distance of at least 8 m from the center of the detection zone. The distance selected is to ensure that the source is not affecting the ambient background at the monitor.
- d) With the SRPM operational, start moving the source through the middle of the detection zone at the appropriate speed. The source shall be configured such that as it enters the detection zone, an occupancy is initiated if occupancy sensors are used. The occupancy shall not be initiated until the source enters the detection zone.
- e) Record the response of the SRPM as the source passes through the detection zone. If the SRPM alarms or indicates that the background has changed, the trial can be considered complete and the source can be returned to the starting point.
- f) Repeat step c), step d), and step e) for a total of three (3) trials with a time interval of at least 1 min between each trial.
- g) Repeat step c) through step f) using the ^{252}Cf neutron source assembly from 6.4.1.
- h) The results are considered acceptable if the SRPM alarms as appropriate for the source or indicates that the background has changed for each trial.

6.8 Radionuclide identification

6.8.1 General

6.8.1.1 Test method for dynamic or static measurement

The test for either dynamic (see 6.1.6) or static (6.1.7) measurements shall consist of ten (10) consecutive trials for each radionuclide in each configuration as required for that monitor's application. The recorded results shall include the confidence indicator(s).

6.8.1.2 Acceptance Criteria

The performance is acceptable when the displayed and associated data file identification results are complete and correct in 9 out of 10 consecutive trials (see Annex C for information regarding the analysis process). For the simultaneous test, both radionuclides shall be correctly and completely identified. Additional information regarding the identification of uranium and plutonium can be found in Table A.1.

6.8.2 Radionuclide identification list

NOTE—IAEA Safety Guide No. RS-G-1.9 contains a list of radionuclides and their category.

6.8.2.1 Requirement

The manufacturer shall provide a list of the radionuclides the monitor can identify. The list shall contain at a minimum those radionuclides and materials shown in Table 3.

Table 3—Radionuclide library

²⁴¹ Am	⁶⁷ Ga	²³² Th	⁴⁰ K
¹³³ Ba	¹³¹ I	¹⁹² Ir	²³⁵ U
⁵⁷ Co	^{99m} Tc	DU	²³⁸ U
⁶⁰ Co	²⁰¹ Tl	HEU	²³⁹ Pu
¹³⁷ Cs	²²⁶ Ra	WGPu	

6.8.2.2 Test method

Verify that the requirement is met by review of manufacturer's provided information and the installed identification library.

6.8.3 Single radionuclide identification

6.8.3.1 Requirement

SRPMs shall be able to identify the radionuclides and materials listed in Table 4 in the dynamic (see 6.1.6) and static (see 6.1.7) modes.

6.8.3.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.

- b) When the unit is operational, perform the dynamic test by passing the ^{241}Am source from Table 4 horizontally through the bottom of the detection zone at the speed applicable to the monitor (Table 2). Record all identification results and confidence indicator(s) reported by the SRPM. Reset the alarm after the trial, if applicable.
- c) Repeat the process stated in step b) for a total of 10 trials. There shall be a 10 s minimum delay between each trial with the source either positioned at a distance where it does not affect the background at the SRPM location or shielded during the delay.
- d) Repeat step b) and step c) at the middle and top of the detection zone.
- e) Repeat step b), step c), and step d) using the remaining unshielded sources listed in Table 4 and the medical radionuclides (^{67}Ga , $^{99\text{m}}\text{Tc}$, ^{131}I , and ^{201}Tl surrounded by 8 cm ($\pm 10\%$) of polymethyl methacrylate (PMMA) to represent in-vivo configurations).
- f) To verify the static measurement portion of the test (see 6.1.7), perform the following. The static test verifies the identification capabilities and background update technique to ensure that a fixed object does not affect the background.
 - 1) Per the manufacturer's instructions, set up the SRPM to perform fixed object measurements. This may require the user to perform some action to manually initiate a measurement.
 - 2) Position the ^{241}Am source from Table 4 at the bottom center of the detection zone and at the required evaluation distance.
 - 3) Initiate a measurement for the specified static measurement time as shown in Table 2.
 - 4) Record all identification results and confidence indicator(s). Reset the alarm after the trial, if applicable.
 - 5) Repeat the process stated in step f3) and step f4) for a total of ten (10) trials without moving the source.
 - 6) Repeat step f2) through step f5) at the middle and top of the detection zone.
 - 7) Repeat step f2) through f6) using the remaining unshielded sources listed in Table 4 and the medical radionuclides (^{67}Ga , $^{99\text{m}}\text{Tc}$, ^{131}I , and ^{201}Tl surrounded by 8 cm ($\pm 10\%$) PMMA to represent an in-vivo source configuration).
- g) The performance is considered acceptable when the identification results are complete and correct in 9 out of 10 consecutive dynamic and static trials for each source (see Annex A and Annex C for information regarding this analysis process).

6.8.4 Identification of shielded radionuclides

6.8.4.1 Requirement

An SRPM shall be characterized as to its ability to identify shielded material. To perform the characterization, use ^{137}Cs and ^{60}Co sources at the shielded activities stated in Table 4 surrounded by 1 cm of steel and 8 cm of HDPE. The steel and HDPE represent mixed shielding materials (low z to high z) that could surround a source.

Table 4—Test radionuclides and materials^a

Radionuclide	Unshielded activity in μCi ($\pm 20\%$)	Shielded activity in μCi ($\pm 20\%$) ^c
²⁴¹ Am	47 (1.74 MBq)	N/A
⁶⁰ Co	7 (259 kBq)	25 (925 kBq)
¹³⁷ Cs	16 (592 kBq)	85 (3.14 MBq)
⁶⁷ Ga ^b	N/A	94 (3.48 MBq)
¹³¹ I ^b	N/A	23 (851 kBq)
^{99m} Tc ^b	N/A	127 (4.7 MBq)
²⁰¹ Tl ^b	N/A	88 (3.26 MBq)
²²⁶ Ra	8 (296 kBq)	N/A
²³² Th	14 (518 kBq)	N/A
	Fluence rate (gammas/s/cm ²)	
DU ^d	1.34	N/A
HEU ^d	1.44	N/A
WGPu ^d	0.40	N/A

^a Unshielded activity values provide an emission rate of approximately 500 000 photons per second from a source that is encapsulated in 0.25 mm stainless steel. At 500 000 photons per second, ¹³⁷Cs produces an exposure rate of approximately 5 $\mu\text{R}/\text{h}$ at 1 m.

^b The actual activities for medical radionuclides given to patients are much greater than those required in this standard. For ^{99m}Tc stress tests, normal doses are typically between 3 mCi and 5 mCi; bone scans with ^{99m}Tc between 20 mCi and 25 mCi; diagnosis using ¹³¹I between 10 μCi and 30 μCi ; therapy with ¹³¹I between 29 mCi and 300 mCi; ²⁰¹Tl stress tests approximately 4 mCi; and for ⁶⁷Ga between 2 mCi and 5 mCi.

^c Activities are based on 1 cm steel plus 8 cm HDPE for ⁶⁰Co and ¹³⁷Cs, and 8 cm PMMA for ⁶⁷Ga, ¹³¹I, ^{99m}Tc, and ²⁰¹Tl.

^d See 6.1.9 for additional details.

6.8.4.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.
- b) When the unit is operational, perform the dynamic test by passing the shielded ¹³⁷Cs source from Table 4 horizontally through the bottom of the detection zone at the speed applicable to the monitor (Table 2). Record the identification results and the confidence indicator(s). Reset the alarm after the trial, if applicable.
- c) Repeat the process stated in step b) for a total of ten (10) trials. There shall be a 10 s minimum delay between each trial with the source either positioned at a distance where it does not affect the background at the SRPM location or shielded during the delay.
- d) Repeat step b) and step c) at the middle of the detection zone.
- e) Repeat step b), step c), and d) using the shielded ⁶⁰Co source listed in Table 4.
- f) To verify the static measurement portion of the test, perform the following.
 - 1) Per the manufacturer's instructions, set up the SRPM to perform fixed object measurements. This may require the user to perform some action to manually initiate a measurement.
 - 2) Position the shielded ¹³⁷Cs source from Table 4 at the bottom center of the detection zone and at the required evaluation distance as stated in Table 2.
 - 3) Initiate a measurement for the specified static measurement time as shown in Table 2.
 - 4) Record the identification results and the confidence indicator(s). Reset the alarm after the trial, if applicable.

- 5) Repeat the process stated in step f3) and step f4) for a total of ten (10) trials without moving the source.
- 6) Repeat step f2) through step f5) at the middle of the detection zone.
- 7) Repeat step f2) through step f6) using the shielded ^{60}Co source listed in Table 4.
- g) Record the number of complete and correct identifications (see Annex C for information regarding this analysis process).
- h) The results are considered acceptable if the identifications are complete and correct in 9 out of 10 consecutive dynamic and static trials for each source.

6.8.5 Radionuclide not in library

6.8.5.1 Requirements

An SRPM shall alarm and indicate the presence of a radiation source (e.g., “not in library,” “unknown”) when exposed to radioactive material that it is not able to identify with a sufficiently high confidence as defined by the manufacturer.

6.8.5.2 Test method

- a) Select a radionuclide from Table 4. A single energy or simple spectrum source is recommended.
- b) Access the source identification library and following guidance provided by the manufacturer, de-select the radionuclide from the identification list.
- c) Set up the SRPM in accordance to Table 2.
- d) When the unit is operational, perform the dynamic test by passing the selected source horizontally through the middle of the detection zone at the speed applicable to the monitor (Table 2). Record the identification results and the confidence indicator(s). Reset the alarm after the trial, if applicable.
- e) Repeat the process stated in step d) for a total of ten (10) trials. There shall be a 10 s minimum delay between each trial with the source either positioned at a distance where it does not affect the background at the SRPM location or shielded during the delay.
- f) To verify the static measurement portion of the test, perform the following.
 - 1) Per the manufacturer’s instructions, set up the SRPM to perform fixed object measurements. This may require the user to perform some action to manually initiate a measurement.
 - 2) Position the test source from Table 4 at the middle center of the detection zone and at the required evaluation distance.
 - 3) Initiate a measurement for the specified static measurement time as shown in Table 2.
 - 4) Record the identification results and the confidence indicator(s). Reset the alarm after the trial, if applicable.
 - 5) Repeat the process stated in step f3) and step f4) for a total of ten (10) trials without removing the source from the detection zone.
- g) The results are considered acceptable if the response from each trial meets the requirements stated in 6.8.5.1.

6.8.6 Simultaneous radionuclide identification

6.8.6.1 Requirements

SRPMs shall have the ability to identify more than one radionuclide simultaneously.

NOTE—The NORM requirement is not applicable to pedestrian monitors.

6.8.6.2 Test method

- a) Set up the SRPM in accordance with Table 2 and 6.1.5.
- b) Prepare to perform the test using the following source combinations:

- ^{137}Cs + DU
- $^{99\text{m}}\text{Tc}$ + HEU
- ^{201}Tl + HEU
- ^{67}Ga + HEU
- ^{131}I + WGPu
- NORM + HEU
- NORM + WGPu

Other than NORM, each source shall be at the activity and configuration stated in Table 4. As part of the test preparation process, measure and record the exposure rate (using equipment such as that in 6.1.4) from each source configuration at a distance of 50 cm from the center of the source configuration.

- c) When the SRPM is operational, pass one of the source combinations horizontally through the middle of the detection zone at the speed applicable to the monitor type (Table 2).
- d) Record the identification results and the confidence indicator(s). Reset the alarm after the trial, if applicable.
- e) Repeat the process stated in step c) and step d) for a total of ten (10) trials. There shall be a 10 s minimum delay between each trial with the source combination either positioned at a distance where it does not affect the background at the SRPM location or shielded during the delay.
- f) Repeat step c), step d), and step e) for each source combination.
- g) To verify the static measurement portion of the test, perform the following.
 - 1) Per the manufacturer's instructions, set up the SRPM to perform fixed object measurements. This may require the user to perform some action to manually initiate a measurement.
 - 2) Position a source combination at the middle center of the detection zone and at the required evaluation distance
 - 3) Initiate a measurement for the specified static measurement time as shown in Table 2.
 - 4) Record the identification results and the confidence indicator(s). Reset the alarm after the trial, if applicable.
 - 5) Repeat the process stated in step g3) and step g4) for a total of ten (10) trials without moving the source combination.
 - 6) Repeat step g3), step g4), step g5) for each source combination.

- h) To verify the requirement utilizing NORM for non-pedestrian SRPMs, perform the following steps to prepare the NORM source configuration.
- 1) Assemble the surrogate bulk NORM by surrounding the ^{226}Ra and ^{232}Th sources from Table 4 with 9 cm of PMMA. The sources shall be configured such that neither source shields the other.

NOTE—Point sources are used for this test to ensure reproducibility in the test process. Zircon sand was previously used to represent NORM. Through measurement, it was determined that the radionuclide composition changes from supplier to supplier. Therefore, Zircon sand is not recommended as a consistent representation of NORM. A source of ^{40}K is added to ensure that the surrogate is more representative of NORM seen in commerce even though its effect may be minimal on the low energy portion of the spectrum where photon emissions from the target source material exist.
 - 2) To replicate the existence of the 1460 keV gamma rays that may be emitted by NORM found in commerce, co-locate the source combination from step h1) with a source of ^{40}K (25 kg of potassium fertilizer, ice melt, etc.). Obtain a spectrum from the resulting source configuration using an HPGe detector for the test record.
 - 3) Repeat step c) through step g).
- i) Record the number of complete and correct identifications (see Annex C for information regarding the analysis process) from each trial set. The results are considered acceptable if the identifications are complete and correct in 9 out of 10 consecutive dynamic or static trials for each source combination.

7. Environmental performance requirements

7.1 Ambient temperature

7.1.1 Requirement

The manufacturer shall state if the SRPM is to be operated in an uncontrolled or controlled environment. If the SRPM is designed to operate in an uncontrolled environment, it shall operate over an ambient temperature range from $-30\text{ }^{\circ}\text{C}$ to $55\text{ }^{\circ}\text{C}$. If the SRPM is designed to operate in a controlled environment, it shall operate over an ambient temperature range from $5\text{ }^{\circ}\text{C}$ to $40\text{ }^{\circ}\text{C}$. Operation includes radiation response and component functionality, e.g., occupancy sensors function properly.

The requirement is verified by exposing the monitor to the specified environment and comparing its radiation detection and identification performance before, during, and after exposure to different temperatures.

7.1.2 Test method

This test should be carried out in an environmental chamber. Humidity levels should be low enough to prevent condensation ($<65\%$ RH) and the rate of change of temperature shall not exceed $10\text{ }^{\circ}\text{C}/\text{h}$. The SRPM shall be observed during the entire temperature test and any functional changes recorded (e.g., alarms, fault indications).

- a) Assemble the SRPM in the test chamber and allow 2 h for stabilization at the nominal temperature and RH of $22\text{ }^{\circ}\text{C}$ and $<65\%$ RH. Individual detection assemblies may be removed from shield assemblies (e.g., steel shroud) for testing. Any openings that become exposed to the environment as a result of disassembly shall be covered.

- b) Expose the SRPM to a gamma-ray and neutron radiation field using ^{57}Co , ^{60}Co , and ^{252}Cf , respectively, placed in a location that can be repeated during the test.

NOTE 1—Depending on the monitor's design, it may be necessary to simulate occupancies when performing measurements.

NOTE 2—The radiation sources are used to obtain relative measurements for comparison throughout the test and need not be the same sources as those shown in Table 4. It is necessary that the same sources are used and that they are placed in the same position when obtaining each series of readings.

- c) Record ten (10) gamma readings (i.e., count rates) from the ^{57}Co and ^{60}Co sources, and ten (10) neutron readings from ^{252}Cf .
- d) Calculate and record the mean, standard deviation, and coefficient of variation (COV). The COV should be less than or equal to 12% for the gamma channel. If the COV from the gamma readings is greater than 12%, the radiation level should be increased to reduce the variation between readings. Due to the possible low response of the neutron detector, a $\text{COV} > 12\%$ is acceptable for the neutron channel.
- e) Establish the acceptance range using the technique defined in 6.1.1.
- f) Perform a series of ten (10) radionuclide identifications and record the identification results including the confidence indicators. Obtain at least one spectrum from the 10-trial series. Remove the sources.
- g) For SRPMs designed for use in uncontrolled temperatures:
- 1) Decrease the temperature at a rate of $10\text{ }^{\circ}\text{C/h}$ to $0\text{ }^{\circ}\text{C}$.
 - 2) Allow the SRPM to soak for 4 h. During the last 30 min of the 4 h soak, obtain the SRPM's response with the sources positioned as described in step b); obtain ten (10) readings as described in step c), and identifications as described in step f).
 - 3) Decrease the temperature at a rate of $10\text{ }^{\circ}\text{C/h}$ to $-20\text{ }^{\circ}\text{C}$ and repeat step g2).
 - 4) Decrease the temperature at a rate of $10\text{ }^{\circ}\text{C/h}$ to the low temperature test point of $-30\text{ }^{\circ}\text{C}$ and maintain the temperature for a period of 16 h.
 - 5) At the beginning, middle, and end of the 16 h period, obtain the SRPM's response with the sources positioned as described in step b); obtain ten (10) readings as described in step c), and identifications as described in step f).
 - 6) Following the low temperature soak, increase the temperature at the $10\text{ }^{\circ}\text{C/h}$ rate to $40\text{ }^{\circ}\text{C}$ and repeat step g2).
 - 7) Increase the temperature to the upper temperature test point of $55\text{ }^{\circ}\text{C}$ at a ramp rate of $10\text{ }^{\circ}\text{C/h}$ and maintain that temperature for 16 h.
 - 8) At the beginning, middle, and end of the 16 h period, obtain the SRPM's response with the sources positioned as described in step b); obtain ten (10) readings as described in step c), and identifications as described in step f).
- h) For SRPMs designed for use in controlled temperatures:
- 1) Decrease the temperature at a rate of $10\text{ }^{\circ}\text{C/h}$ to the low temperature test point of $5\text{ }^{\circ}\text{C}$ and maintain the low temperature test point for 16 h.
 - 2) At the beginning, middle, and end of the 16 h period, obtain the SRPM's response with the sources positioned as described in step b); obtain ten (10) readings as described in step c), and identifications as described in step f).
 - 3) Following the low temperature soak, increase the temperature at a rate of $10\text{ }^{\circ}\text{C/h}$ to $30\text{ }^{\circ}\text{C}$ and allow the SRPM to soak for 4 h.

- 4) During the last 30 min of the 4 h soak, obtain the SRPM's response with the sources positioned as described in step b); obtain ten (10) readings as described in step c), and identifications as described in step f).
- 5) Increase the temperature at a rate of 10 °C/h to the upper temperature test point of 40 °C.
- 6) Maintain the low temperature test point for 16 h and repeat step h2).
- i) Following the upper temperature exposure, return the temperature to the nominal value (22 °C) at the 10 °C/h rate and after a 2 h stabilization period, obtain the SRPM's response with the sources positioned as described in step b), obtain ten (10) readings as described in step c), and identifications as described in step f).
- j) Analyze the results based on 6.1.2.

7.2 Relative humidity

7.2.1 Requirement

The SRPM shall be able to operate during and after exposure to RH levels of up to 93% at an ambient temperature of +40 °C. The requirement is verified by exposing the monitor to the specified environment and comparing its detection and identification performance before, during, and after exposure. There shall not be any observable effects from the exposure. If the SRPM readings collected during the temperature test indicated susceptibility at the humidity temperature test point, a failure of the humidity test cannot conclusively be attributed to humidity.

7.2.2 Test method

- a) Assemble the SRPM in the test chamber and allow 2 h for stabilization at 22 °C and 40% RH. Individual detection assemblies may be removed from shield assemblies (e.g., steel shroud) for testing. Any openings that become exposed to the environment as a result of disassembly shall be covered.
- b) Expose the SRPM to a gamma-ray and neutron radiation field using ⁵⁷Co, ⁶⁰Co, and ²⁵²Cf, respectively, placed in a location that can be repeated during the test.

NOTE 1—Depending on the monitor's design, it may be necessary to simulate occupancies when performing measurements.

NOTE 2—The radiation sources are used to obtain relative measurements for comparison throughout the test and need not be the same sources as those shown in Table 4. It is necessary that the same sources are used and that they are placed in the same position when obtaining each series of readings.

- c) Record ten (10) gamma readings (i.e., count rates) from the ⁵⁷Co and ⁶⁰Co sources, and ten (10) neutron readings from ²⁵²Cf.
- d) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12% for the gamma channel. If the COV from the gamma readings is greater than 12%, the radiation level should be increased to reduce the variation between readings. Due to the possible low response of the neutron detector, a COV > 12% is acceptable for the neutron channel.
- e) Establish the acceptance range using the technique defined in 6.1.1.
- f) Perform a series of ten (10) radionuclide identifications and record the identification results including the confidence indicators. Obtain at least one spectrum from the 10-trial series. Remove the sources.
- g) Increase the temperature to 40 °C at a rate of 10 °C/h.

- h) Repeat step b) through step f) as the nominal 40 °C values.

NOTE—This second set of nominal values is obtained to help determine whether an indicated susceptibility was from the increase in humidity alone.

- i) With the chamber at 40 °C, increase the humidity at a rate not exceeding 10% RH/h until attaining $93 \pm 3\%$ RH.
- j) Maintain the humidity and temperature conditions for 16 h.
- k) Obtain the SRPM's response as described in step b), step c), and step f) at the beginning, middle, and end of the 16 h period with each source in the same position as that used to establish the acceptance range or nominal readings.
- l) Reduce the RH to 65% at a rate of 10% RH/h while maintaining the temperature at 40 °C.
- m) Maintain the temperature and humidity at 40 °C and 65% RH for a minimum of 4 h.
- n) During the last 30 min of the 40 °C and 65% RH stabilization period, obtain the SRPM's response as described in step b), step c), and step f).
- o) Analyze the results based on 6.1.2 using the 40 °C values obtained in step h).
- p) Reduce the temperature to 22 °C at a rate of 10 °C/h and the RH to 40% over the same time interval.
- q) Allow the conditions to stabilize for a minimum of 4 h.
- r) During the last 30 min of the 22 °C and 40% RH stabilization period, obtain the SRPM's response as described in step b), step c), and step f).
- s) Inspect the components that were in the environmental chamber for any observable effects from the exposure and record the results.
- t) Analyze the final results based on 6.1.2 using the 22 °C values.

7.3 Moisture and dust protection (not required for SRPMs designed for use in controlled environments)

7.3.1 Requirement

Components designed for use in an unprotected environment (e.g., detection assembly) shall meet the requirements stated for IP code 54 (see IEC 60529), protected from the ingress of dust and splashing water. For IP54, the ingress of dust is not totally prevented, but dust shall not penetrate in a quantity to interfere with satisfactory operation of the instrument or to impair safety (level "5" of the IP code), and water splashed against the enclosure from any direction shall have no harmful effects (level "4" of the IP code). If the monitor uses multiple identical detector assemblies, it is only necessary to test one assembly.

For monitors used where salt mist exists (e.g., shipping ports), salt mist testing should be performed as agreed upon by the manufacturer and purchaser in accordance with IEC 60068-2-11.

7.3.2 Test method—Dust

- a) Place the detection assembly(s) and any other component that may be operated in the same environment in a dust chamber as described in IEC 60529, category 2—interior of enclosure is at the same pressure as the pressure outside of the chamber.
- b) Expose the SRPM to a gamma-ray and neutron radiation field using ^{57}Co , ^{60}Co , and ^{252}Cf , respectively, placed in a location that can be repeated during the test.

NOTE 1— Depending on the monitor's design, it may be necessary to simulate occupancies when performing measurements.

NOTE 2— The radiation sources are used to obtain relative measurements for comparison throughout the test and need not be the same sources as those shown in Table 4. It is necessary that the same sources are used and that they are placed in the same position when obtaining each series of readings.

- c) Record ten (10) gamma readings (i.e., count rates) from the ^{57}Co and ^{60}Co sources, and ten (10) neutron readings from ^{252}Cf .
- d) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12% for the gamma channel. If the COV from the gamma readings is greater than 12%, the radiation level should be increased to reduce the variation between readings. Due to the possible low response of the neutron detector, a COV > 12% is acceptable for the neutron channel.
- e) Establish the acceptance range using the technique defined in 6.1.1.
- f) Perform a series of ten (10) radionuclide identifications and record the identification results including the confidence indicators. Obtain at least one spectrum from the 10-trial series. Remove the sources.
- g) Expose the assembly to the dust environment for a period of 1 h.
- h) Following the dust exposure, obtain the SRPM's response as described in step b), step c), and step f) with each source in the same position as that used to establish the acceptance range or nominal readings.
- i) Inspect the assembly to determine the extent of dust ingress. The protection is satisfactory if, on inspection, powder has not accumulated in a quantity or location such that, as with any other kind of dust, it could interfere with the correct operation of the monitor or impair safety.
- j) Analyze the results based on 6.1.2.

7.3.3 Test method—Moisture

- a) Prior to positioning the SRPM components (typically the detection assembly and any other component that are mounted on the assembly) for test, set up the water system as defined in IEC 60529, level 4.
- b) Turn on the water flow to the spray nozzle.
- c) Adjust the water pressure to be constant from 50 kPa to 150 kPa and the flow rate according to the spray nozzle requirements as described in IEC 60529.
- d) Adjust the water temperature to be not more than 5 K from the temperature of the SRPM under test.
- e) Turn off the water and position the detection assembly as it would be oriented in the field.
- f) Expose the SRPM to a gamma-ray and neutron radiation field using ^{57}Co , ^{60}Co , and ^{252}Cf placed in a location that can be repeated during the test.

NOTE 1— The radiation sources are used to obtain relative measurements for comparison throughout the test and need not be the same sources as those shown in Table 4. It is necessary that the same sources are used and that they are placed in the same position when obtaining each series of readings.

NOTE 2— Depending on the monitor's design, it may be necessary to simulate occupancies when performing measurements.

- g) Record ten (10) readings (i.e., count rates) with the ^{57}Co , ^{60}Co , and ^{252}Cf sources present.
- h) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12%. If the COV is greater than 12%, the radiation level should be increased to reduce the

variation between readings. Due to the possible low response of the neutron detector, a COV > 12% is acceptable.

- i) Establish the acceptance range using the technique defined in 6.1.1.
- j) Perform a series of ten (10) radionuclide identifications and record the identification results including the confidence indicators. Obtain at least one spectrum from the 10-trial series. Remove the sources.
- k) Establish the water exposure time using an exposure rate of 1 min/m² of surface area. The minimum exposure time shall be 5 min for the assembly under test.
- l) Start the water exposure. Move the nozzle to ensure that each surface area is exposed to the water spray while maintaining a distance of approximately 2 m from the surface of the assembly under test.
- m) Observe the SRPM response while being exposed to the water spray and record any functional changes that may occur (e.g., alarms, fault indications).
- n) Following the moisture exposure, obtain the SRPM's response as described in step f), step g), and step j) with each source in the same position as that used to establish the acceptance range or nominal readings.
- o) Inspect the assembly to determine the extent of moisture ingress. The protection is satisfactory if, on inspection, moisture has not accumulated in a quantity or location such that it could interfere with the correct operation of the monitor or impair safety.
- p) Analyze the results based on 6.1.2.

8. Electrical and electromagnetic performance requirements

8.1 Power supply

8.1.1 Requirement

Line-powered SRPMs shall be designed to operate from a single-phase ac supply voltage of 100 V to 240 V and from 47 Hz to 63 Hz. Testing is not required when the manufacturer provides evidence that only compliant power supply(s) are used as would be indicated through a stamp or other method on the power supply.

8.1.2 Test method

- a) Adjust the voltage and frequency of a variable power supply to the nominal values based on the input power requirements of the SRPM and power up the SRPM.
- b) Expose the SRPM to a gamma-ray and neutron radiation field using ⁵⁷Co, ⁶⁰Co, and ²⁵²Cf, respectively, placed in a location that can be repeated during the test.

NOTE 1— Depending on the monitor's design, it may be necessary to simulate occupancies when performing measurements.

NOTE 2— The radiation sources are used to obtain relative measurements for comparison throughout the test and need not be the same sources as those shown in Table 4. It is necessary that the same sources are used and that they are placed in the same position when obtaining each series of readings.

- c) Record ten (10) gamma readings (i.e., count rates) from the ⁵⁷Co and ⁶⁰Co sources, and ten (10) neutron readings from ²⁵²Cf.

- d) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12% for the gamma channel. If the COV from the gamma readings is greater than 12%, the radiation level should be increased to reduce the variation between readings. Due to the possible low response of the neutron detector, a COV > 12% is acceptable for the neutron channel.
- e) Establish the acceptance range using the technique defined in 6.1.1.
- f) Perform a series of ten (10) radionuclide identifications and record the identification results including the confidence indicators. Obtain at least one spectrum from the 10-trial series. Remove the sources.
- g) Increase the supply voltage to 12% above the nominal value and repeat step b), step c), and step f) with the sources in the same location as that used for the nominal readings.
- h) Decrease the supply voltage to 12% below the nominal value and repeat step b), step c), and step f) with the sources in the same location as that used for the nominal readings.
- i) Repeat step g) at the nominal supply voltage with the line frequency at 3% above and 3% below the nominal frequency (58 Hz to 62 Hz).
- j) Observe the SRPM response while being exposed to each test condition and record any functional changes that may occur (e.g., alarms, fault indications).
- k) Following the voltage and frequency tests, obtain the SRPM's response as described in step b), step c), and step f) with each source in the same position as that used to establish the acceptance range or nominal readings.
- l) Analyze the results based on 6.1.2.

8.2 Electrostatic discharge (ESD)

8.2.1 Requirement (IEC 61000-4-2, severity level 3)

The SRPM shall function properly after exposure to ESDs at intensities of up to 6 kV using the contact discharge technique.

8.2.2 Test method

- a) Prior to proceeding with the test, discuss the test including setup and ESD exposure levels with the manufacturer to establish appropriate discharge points. Discharge points should be selected based on user accessibility (e.g., door handles, latches, hinges).
- b) Set up the SRPM for the test as described in IEC 61000-4-2 and allow the SRPM to become operational.
- c) Expose the SRPM to a gamma-ray and neutron radiation field using ^{57}Co , ^{60}Co , and ^{252}Cf placed in a location that can be repeated after the test.

NOTE—The radiation sources are used to obtain relative measurements for comparison throughout the test and need not be the same sources as those shown in Table 4. It is necessary that the same sources are used and that they are placed in the same position when obtaining each series of readings.

- d) Record ten (10) gamma readings (i.e., count rates) from the ^{57}Co and ^{60}Co sources, and ten (10) neutron readings from ^{252}Cf .
- e) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12% for the gamma channel. If the COV from the gamma readings is greater than 12%, the radiation level should be increased to reduce the variation between readings. Due to the possible low response of the neutron detector, a COV > 12% is acceptable for the neutron channel.

- f) Establish the acceptance range using the technique defined in 6.1.1.
- g) Perform a series of ten radionuclide identifications and record the identification results including the confidence indicators. Obtain at least one spectrum from the 10-trial series. Remove the sources.
- h) Using the contact discharge technique as described in the reference standard, expose the SRPM to ten (10) positive and ten (10) negative discharges per discharge point with a 1 s recovery time between each discharge.
- i) Observe the SRPM's response, and record whether any reproducible changes (e.g., alarms, spurious indications) occur.
- j) When the ESD exposures are complete, repeat step c), step d), and step g).
- k) Analyze the results based on 6.1.2.

8.3 Radio frequency (RF) susceptibility

8.3.1 Requirement (IEC 61000-4-3, severity level 3)

The SRPM should not be affected by RF fields over the frequency range of 80 MHz to 6000 MHz. The RF field intensity shall be 10 volts per meter (V/m) over the frequency range from 80 MHz to 1000 MHz. For frequencies over 1000 MHz, the intensity is 3 V/m.

8.3.2 Test method

NOTE 1—An alternative test method may be used. When used, the alternative method must be fully described including its traceability to the test described in IEC 61000-4-3.

- a) Set up the SRPM for the test as described in IEC 61000-4-3.
- b) Switch on the SRPM and allow it to become operational.
- c) Expose the SRPM to a neutron radiation field using ^{252}Cf placed in a location that can be repeated during the test.

NOTE 2—The addition of gamma sources is not required because readings are high enough to allow for positive or negative changes in response to be observed during the RF exposure. Because the neutron response is low, a neutron source is added to elevate the response such that changes can be observed.

- d) Record ten (10) readings (i.e., count rates) with the ^{252}Cf source present.
- e) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12%, but due to the low response of the neutron detector, a COV > 12% is acceptable.
- f) Establish the acceptance range using the technique defined in 6.1.1.

NOTE 3—Due to the physical size of a portal monitor system, it may be necessary to reposition the system within the RF field to ensure that each surface area is exposed at the proper intensity. If the monitor is designed where there is a continuous RF shielded surface (e.g., the side of a metal cabinet without vents or seams), that side does not need to be tested.

- g) Set up the antenna in the vertical orientation and the RF system to produce the required intensity over a frequency range of 80 MHz to 6000 MHz that is 80% amplitude modulated with a 1 kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not >1% of the fundamental (previous) frequency. Dwell time at each frequency should be chosen based on the SRPM's response time, but should not be <3 s.

- h) If possible, set up the SRPM to collect and store background spectra during the scan at the same or similar time interval (3 s). This will allow correlation between exposure frequency and spectral changes, if they occur.
- i) With the SRPM performing measurements, start the RF exposure.
- j) Observe the readings and record any operational or functional changes that occur (e.g., reproducible alarm actuation, spurious changes in response, changes in status).
- k) Repeat step i) and step j) in all orientations relative to the RF emission source to verify compliance to the requirement. However, an orientation of the monitor that provides a continuous RF shielded surface (e.g., the side of a metal cabinet without vents or seams) does not need to be tested.
- l) Set up the antenna in the horizontal orientation and repeat step a) through step k).
- m) In addition to checking for spectral changes, analyze the results based on 6.1.2.

8.4 Radiated emissions

8.4.1 Requirement

The EM fields emitted by the SRPM at 3 m shall be less than what is shown in Table 5, as described in 47 CFR 15.109 rules for unintentional radiators Class A digital devices.

Table 5—Emission frequency range

Frequency range (MHz)	Field strength (microvolts/meter)
30–88	100
88–216	150
216–960	200
>960	500

8.4.2 Test method (based on ANSI C63.4)

- a) Place the SRPM in an area with a low and controllable RF environment (e.g., anechoic chamber).
- b) Position an antenna 3 m from the assembly.
- c) With the SRPM off, obtain a background RF spectrum using a scanning bandwidth of 50 kHz.
- d) Switch the SRPM on.
- e) Once the SPRM is operational, perform an RF scan with the antenna in the vertical orientation. Rotate the SRPM as needed to ensure that each side is monitored for emissions. Monitoring the top and bottom is not required.
- f) Record emissions that are greater than the values stated in Table 5.
- g) If no RF emissions are observed, proceed to step h). If observed RF emissions are greater than the values stated in Table 5, additional testing is not required.
- h) Rotate the antenna to the horizontal orientation and repeat step e) and step f).

8.5 Conducted emissions

8.5.1 Requirement

An SRPM shall not produce conducted EM emissions back onto the ac power line grid that are greater than the limits stated in 47 CFR 15.107 for Class A unintentional emitters. Devices shall be tested to demonstrate compliance with the conducted limits if the device (operational or non-operational) is either directly or indirectly connected to the ac power line.

8.5.2 Test method

- a) Set up an appropriate line impedance stabilization network.
- b) With the SRPM off, measure the RF voltage between each power line and ground at the power terminal.
- c) Verify that the conducted emissions within the band from 150 kHz to 30 MHz do not exceed the limits shown in Table 6.
- d) Switch the SRPM on and repeat the measurement process with the unit operating normally.

Table 6—Conducted emission limits

Frequency range (MHz)	Conducted limit (dB μ V)	
	Quasi-peak	Average
0.15–0.5	79	66
0.5–30	73	60

8.6 Conducted disturbances induced by bursts and radio frequencies

8.6.1 Requirement (IEC 61000-4-6, severity 3)

The SRPM should not be affected by RF fields that can be conducted onto the unit through an external conducting cable. SRPMs that have shielded (i.e., placed in conduit) external conducting cables are excluded.

8.6.2 Test method

- a) Set up the SRPM for the test as described in IEC 61000-4-6.
- b) Switch on the SRPM and allow it to become operational.
- c) Expose the SRPM to a neutron radiation field using ^{252}Cf placed in a location that can be repeated during the test.

NOTE—The addition of gamma sources is not required because readings are high enough to allow for positive or negative changes in response to be observed during the RF exposure. Because the neutron response is low, a neutron source is added to elevate the response such that changes can be observed.

- d) Record ten (10) readings (i.e., count rates) with the ^{252}Cf source present.
- e) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12%, but due to the possible low response of the neutron detector, a COV > 12% is acceptable.

- f) Establish the acceptance range using the technique defined in 6.1.1.
- g) Set up the RF system to inject an RF signal into the power line using the appropriate coupling device over the frequency range of 150 kHz to 80 MHz at an intensity of 140 dB (μ V) (measured unmodulated) 80% amplitude modulated with a 1 kHz sine wave. The test should be performed using an automated sweep at a frequency change rate not $>1\%$ of the fundamental (previous) frequency. Dwell time at each frequency should be chosen based on the SRPM's response time, but should not be <3 s.
- h) If possible, set up the SRPM to collect and store background spectra during the scan at the same or similar time interval (3 s). This will allow correlation between exposure frequency and spectral changes, if they occur.
- i) With the SRPM performing measurements, start the conducted RF exposure.
- j) Observe the readings and record any operational or functional changes that occur (e.g., reproducible alarm actuation, spurious changes in response, changes in status).
- k) In addition to checking for spectral changes, analyze the results based on 6.1.2.

8.7 Surges and oscillatory waves

8.7.1 Requirement (IEC 61000-4-5 and IEC 61000-4-12, severity level 3)

An SRPM should not be affected by surges or oscillatory waves of up to 2 kV in amplitude that are classified as "combination waves" (damped surges) with rise/decay times of 1.2/50 μ s (open-circuit voltage waveform) and 8/20 μ s (short-circuit current waveform) or "ring waves" (single-shot oscillatory transients or non-repetitive damped oscillatory transients) with 0.5 μ s rise time and 100 kHz oscillation frequency, when such waves are conducted into the monitor through a power line.

8.7.2 Test method

- a) Set up the SRPM and field generation equipment for the test as described in IEC 61000-4-5 and IEC 61000-4-12.
- b) Switch on the SRPM and allow it to become operational.
- c) With the SRPM performing measurements including collecting and storing spectra, apply ten (10) combination wave pulses to the monitor power cable. The minimum time between each pulse shall be 1 min. Each pulse shall consist of a combination wave (1.2/50 μ s and 8/20 μ s) at an intensity of 2 kV.
- d) Repeat the procedure for each power cable, if more than one cable exists.
- e) Repeat the test using 2 kV ring wave pulses.
- f) Observe the radiation response and record any operational or functional changes that occur (e.g., reproducible alarm actuation, spurious changes in response, changes in status).
- g) In addition to checking for spectral changes, analyze the results based on 6.1.2.

9. Mechanical performance requirements

9.1 Vibration

9.1.1 Requirement

An SRPM shall function normally when exposed to vibrations associated with equipment installed in non-weather protected locations of up to $0.5 g_n$ over a frequency range from 10 Hz to 150 Hz. The physical condition of the monitor should not be affected by exposure (e.g., solder joints shall hold; nuts and bolts shall not come loose).

9.1.2 Test method

- a) Mount components that will be exposed to the vibratory environment (i.e., detection assembly and stand) to the vibration system as they would be mounted when used in the field (i.e., mechanically and electrically connected and oriented the same as when installed in the field).
- b) Expose the SRPM to a gamma-ray and neutron radiation field using ^{57}Co , ^{60}Co , and ^{252}Cf placed in a location that can be repeated during the test.

NOTE 1— The radiation sources are used to obtain relative measurements for comparison throughout the test and need not be the same sources as those shown in Table 4. It is necessary that the same sources are used and that they are placed in the same position when obtaining each series of readings.

NOTE 2— Depending on the monitor's design, it may be necessary to simulate occupancies when performing measurements.

- c) Record ten (10) readings (i.e., count rates) with the ^{57}Co , ^{60}Co , and ^{252}Cf sources present.
- d) Calculate and record the mean, standard deviation, and COV. The COV should be less than or equal to 12%. If the COV is greater than 12%, the radiation level should be increased to reduce the variation between readings. Due to the possible low response of the neutron detector, a $\text{COV} > 12\%$ is acceptable.
- e) Establish the acceptance range using the technique defined in 6.1.1.
- f) Perform a series of ten (10) radionuclide identifications and record the identification results including the confidence indicators. Obtain at least one spectrum from the 10-trial series.
- g) If possible, set up the monitor to collect and store spectra during the test for later review.
- h) With the radiation sources present, subject the monitor to ten (10) 2-min logarithmic sweep cycles (up and down) at an intensity of $0.5 g_n$ over a frequency range from 10 Hz to 150 Hz.
- i) During the vibration, observe the gamma and neutron readings and document any excursions that are outside of the acceptance range.
- j) Following the vibration, inspect the SRPM for any damage or loose components.
- k) Repeat step b), step c), and step f).
- l) In addition to checking for spectral changes that may have occurred during the vibration exposure, analyze the results based on 6.1.2.

9.2 Microphonics/impact (IEC 60068-2-75)

9.2.1 Requirement

An SRPM shall be unaffected by microphonic conditions such as those that may occur from low-intensity sharp contacts at energies of up to 1.0 joule (J).

9.2.2 Test method

- a) Switch on the SRPM and allow it to become operational.

NOTE—Depending on the monitor's design, it may be necessary to simulate occupancies when performing measurements.

- b) Using an appropriate test device (e.g., spring hammer), expose each detector assembly to a series of 1.0 J impacts and observe the SRPM response. An impact should be performed at three locations close to the electronics and at three other locations close to the detectors inside the monitor assembly for a total of six impacts.
- c) The test is acceptable if no alarms or other spurious indications occur.

10. Documentation

10.1 Type test report

The manufacturer shall make available, at the request of the purchaser, the report on the type tests performed to the requirements of this standard.

10.2 Report

The manufacturer shall provide the following information, as a minimum:

- Contact information for the manufacturer including name, address, telephone number, fax number, email address, etc.
- Type of portal monitor, detector, and types of radiation the monitor is designed to measure
- Mounting distance between detection assemblies, as appropriate
- Power supply requirements
- Recommended operational parameters such as detector response, false alarm probability, alarm thresholds, operating parameters, and libraries
- Static measurement time
- Size of the detection zone
- Complete description of the monitor
- Description of the occupancy sensors and the occupancy process, when applicable
- Enclosure specification classification
- Inclusion of any hazardous material that may require additional regulation (such as radionuclide check source, pressurized gases, corrosive materials)

- List of radionuclides that are identified by the monitor
- Description of the confidence level indication
- Over-range exposure rate values for gross counting and identification

10.3 Operation and maintenance manual

The manufacturer shall supply an operation and maintenance manual containing the following information to the user:

- Operating instructions and restrictions
- Module connection schematic
- Electrical connection schematic
- Mounting instructions
- Spare parts list
- Troubleshooting guide
- Description and protocol for communication methods of transmitting and receiving data

Annex A

(informative)

Detection and identification of plutonium and uranium

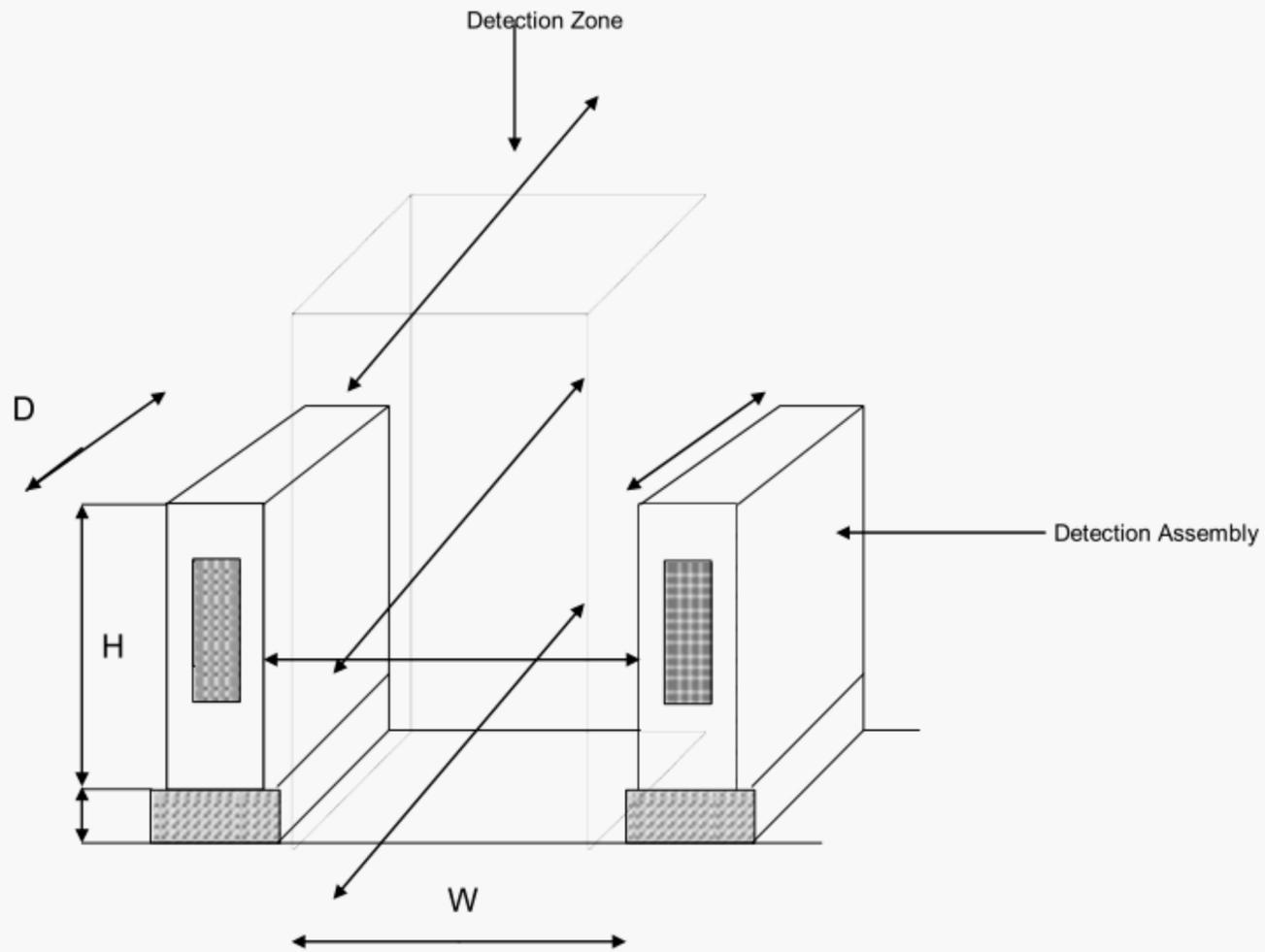
Table A.1—Uranium/plutonium detection and identification guidance

U grade	Definition	Acceptable identification	Comment
U ore	Natural U, i.e., ^{235}U and ^{238}U in natural abundance and in secular equilibrium	^{226}Ra , ^{238}U , or U	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 $^{234\text{m}}\text{Pa}$ being short lived daughters of ^{238}U are still present)	U, or $^{235}\text{U}+^{238}\text{U}$	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 .	U, LEU, ^{235}U , or $^{235}\text{U}+^{238}\text{U}$	May include a sub-class that could indicate slightly enriched uranium U enriched to a ^{235}U concentration of 0.9 % to 2 %.
Highly enriched uranium (HEU)	Enriched U up to a ^{235}U concentration at higher than 20% ^{235}U	U, HEU, ^{235}U , or $^{235}\text{U}+^{238}\text{U}$	
Depleted uranium (DU)	U with lower than natural abundance of ^{235}U	U, DU, $^{235}\text{U}+^{238}\text{U}$, or ^{238}U	Although DU is not typically considered an SNM, DU will generally be considered as SNM for the purposes of instrument identification due to its hazards and masking capability.
^{241}Am	^{241}Am that does not contain Plutonium, such as smoke detectors, gauging sources, etc.	^{241}Am	Usually identified by the 59.5 keV spectral peaks. False Plutonium identification can lead to operational problems.
Weapons grade plutonium (WGPu)	Primarily ^{239}Pu , with less than 6% ^{240}Pu	^{239}Pu , WGPu	WGPu contains ^{241}Am ; the 59.5 keV gamma-ray energy is usually detected. 375 and 414 keV spectral peaks may also be used to identify. Minimal neutron emission. Difficult to distinguish from RGPu by spectroscopy.
Reactor grade plutonium (RGPu)	Primarily ^{239}Pu with ~15% ^{240}Pu	^{239}Pu , RGPu	RGPu contains ^{241}Am and the same radionuclides as WGPu. Primary observable difference is higher neutron emission. Difficult to distinguish from WGPu unless it causes a neutron alarm.
^{238}Pu	~90% ^{240}Pu + ^{238}Pu	^{238}Pu , ^{240}Pu	Radioisotope thermal generators use these radionuclides. Unlikely to be encountered in a portal. Likely neutron alarm is primary signature of Pu-240.

Annex B

(informative)

Detection zone diagram



W = width of the detection zone

H = height of the detection zone

The arrows indicate the movement of radiation sources through the detection zone.

Figure B.1—Example of a two-sided system

Annex C

(informative)

Identification performance guidance

This annex is a summary of the definitions used to characterize identification results for spectrometric systems. The described technique was developed as a means to analyze results obtained from spectral injection studies at the International Atomic Energy Agency.

- a) Complete & correct (C&C)
- Source “X” identified as “X”
 - Sources “X+Y” identified as “X+Y”

Example 1

- $^{235}\text{U} \rightarrow ^{235}\text{U}$
- $^{235}\text{U} \rightarrow ^{235}\text{U} + ^{40}\text{K}$
- $^{235}\text{U} \rightarrow ^{235}\text{U} + ^{40}\text{K} + \text{Th}$
- $^{235}\text{U} \rightarrow ^{235}\text{U} + ^{40}\text{K} + \text{Th} + \text{Ra}$
- $^{235}\text{U} + ^{67}\text{Ga} \rightarrow ^{235}\text{U} + ^{67}\text{Ga} + ^{40}\text{K} + \text{Th} + \text{Ra}$

“Y” includes daughters that may be present.

- b) Incomplete
- Source “X+Y” identified as “X” or “Y”

Example 2

- $^{235}\text{U} + ^{226}\text{Ra} \rightarrow ^{226}\text{Ra}$

- c) Incorrect
- Source “X” identified as “X + Y”.

Example 3

- $^{235}\text{U} \rightarrow ^{235}\text{U} + ^{237}\text{Np}$
- $^{67}\text{Ga} \rightarrow ^{235}\text{U} + ^{67}\text{Ga}$

- d) Incomplete & incorrect (I&I)
- Source “A” being identified as “C”
 - Source “A+B” identified as “C+D”

Example 4

- $^{235}\text{U} \rightarrow ^{67}\text{Ga}$
- $^{235}\text{U} + ^{137}\text{Cs} \rightarrow ^{99\text{m}}\text{Tc} + ^{133}\text{Ba}$

It should be noted that, during field use, identification of certain radionuclides or materials may be more critical than others. For example, the identification of SNM, such as HEU or Pu, when present is critical. If other less critical radionuclides are incorrectly identified with the SNM, such as ^{67}Ga or ^{133}Ba , the results may not be considered a problem for the user. It is very problematic though if the SNM is present and only the less important radionuclides are identified. This is obviously incorrect and should be considered an identification failure.

Based on this operational reality, it may become necessary to *classify* or *categorize* radionuclides as critical or not critical. Although the classification or categorization is an operational concern (i.e., ConOps), the possible need to consider certain radionuclides as more critical than others should be considered.

Table C.1—List of daughters and possible impurities

Radionuclide(s)/Materials	Daughters and possible impurities
^{201}Tl	^{202}Tl
DU	^{235}U , ^{226}Ra
WGPu	^{242}Pu , ^{241}Pu , ^{240}Pu , ^{238}Pu , ^{241}Am , ^{237}U , ^{242}Pa , ^{233}U
HEU	^{238}U , $^{234\text{m}}\text{Pa}$
$^{99\text{m}}\text{Tc}$	^{99}Mo
^{232}Th	^{228}Th , ^{232}U
^{226}Ra	^{214}Bi , ^{214}Pb

Consensus

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