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American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

IEEE
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USA

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(Revision of
ANSI N42.43-2006)

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Secretariat

Institute of Electrical and Electronics Engineers, Inc.

Approved 26 April 2016

American National Standards Institute

Abstract: The operational and performance requirements for transportable and/or mobile radiation monitors used in homeland security applications are specified in this standard. Transportable radiation monitors are designed to be transported to a location and used for a specific task or for a specified period of time and do not require permanent mounting platforms. Mobile monitors are those monitors that are typically in operation on a platform that is in motion.

Keywords: ANSI N42.43, mobile radiation monitors, transportable radiation monitors

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Introduction

This introduction is not part of ANSI N42.43-2016, American National Standard Performance Criteria for Mobile and Transportable Radiation 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 September–October 2006.

Contents

American National Standard Performance Criteria for Mobile and Transportable Radiation Monitors Used for Homeland Security

1. Overview

1.1 Scope

This standard specifies the performance requirements and tests for transportable and mobile radiation monitors that detect and identify radionuclides, and when provided, indicate the presence of neutron radiation. *Transportable radiation monitors* are designed to be transported to a location and used for a specific task or for a specified period of time; they do not require permanent mounting platforms; may be mounted to a vehicle such as a trailer; and are only used when the vehicle is stationary. *Mobile radiation monitors* are typically in operation on a platform that is in motion but that can also be used while stationary. Mobile monitors may be mounted in vehicles including, for example, trailers.

1.2 Purpose

This standard specifies the operational and performance requirements for transportable and mobile radiation monitors used in homeland security applications. Operational requirements established by this standard include radiation detection and radionuclide identification, and those requirements associated with the expected electrical, mechanical, and environmental conditions while in transit and when deployed. The tests described in this standard provide a means to help ensure that a monitor meets the requirements stated.

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 N42.42, American National Standard Data Format Standard for Radiation Detectors Used for Homeland Security.[1]

ASTM B152, Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar.[2]

FCC Part 15, Code of Federal Regulations, Title 47, Part 15 (47 CFR 15).

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

IEC 60068-2-1, Environmental testing—Part 2-1: Tests—Test A: Cold.[3]

IEC 60068-2-2, Environmental testing—Part 2-2: Tests—Test B: Dry heat.

IEC 60068-2-11, Basic environmental testing procedures—Part 2-11: Tests—Test Ka: Salt mist.

IEC 60068-2-18, Environmental testing—Part 2-18: Tests—Test R and guidance: Water.

IEC 60068-2-64, Environmental testing—Part 2-64: Tests—Test Fh: Vibration, broadband random and guidance.

IEC 60068-2-66, Environmental testing—Part 2: Test methods—Test Cx: Damp heat, steady state (unsaturated pressurized vapour).

IEC 60068-2-68, Environmental testing—Part 2-68: Tests—Test L: Dust and sand.

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 62438, Radiation protection instrumentation—Mobile instrumentation for the measurements of photon and neutron radiation in the environment.

IEC 62706, Radiation protection instrumentation—Environmental, electromagnetic and mechanical performance requirements.

ISO 4037-3, X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy—Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence.[4]

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[1] The ANSI N42 publications included in this clause are available from The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).
[2] ASTM publications are available from the American Society for Testing and Materials (http://www.astm.org/).
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[4] ISO publications are available from the ISO Central Secretariat (http://www.iso.org/). ISO publications are also available in the United States from the American National Standards Institute (http://www.ansi.org/).

3. Definitions and acronyms

3.1 Definitions

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

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

area monitor: A radiation monitor that is designed to detect increases in the ambient radiation level within an area either surrounding the detection assembly or adjacent to the detection assembly.

calibrate: To adjust and/or determine the response or reading of a device relative to a series of conventionally true values.

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.

coefficient of variation (COV): The square root of the variance, s^2, divided by the mean value of *n,* the number of readings, multiplied by 100.

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

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

detection zone: Area where radiation measurement takes place for the purposes of detection or identification.

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

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

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

NOTE—The special unit of exposure rate is the roentgen per hour, abbreviated in this standard as R/h.[6]

false alarm: Alarm caused by something other than an increase in measured radiation level or identification of a radionuclide.

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

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

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

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

mobile monitor: A monitor that is typically in operation on a platform that is in motion.

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

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

monitor: Radiation-detection system that measures radiation intensity, compares it to alarm criteria, and produces an alarm if the measured radiation intensity exceeds the criteria.

radioactive material: In this standard, radioactive material includes both special nuclear and other radioactive material unless otherwise specifically noted.

range: All values between the detection threshold and the detection limit.

reading: The indicated or displayed value.

reference point: The position on or within a detection assembly or detector used to set measurement distances or test placement.

response time: For this standard, the time required to update the display or integrate counts obtained from a radiation source.

standard deviation: The positive 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 or monitors made to a specific design to show that the design meets defined specifications.

transportable monitor: A monitor that can be transported to a location and used without requiring a permanent mounting platform.

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

variance (s^2): A measure of dispersion, which is the sum of the squared deviation of observations from their mean divided by one less than the number of observations (n).

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

3.2 Acronyms

COV	coefficient of variation
GMT	Geiger Mueller tube

GPS	global positioning system
HDPE	high-density polyethylene
HPGe	high-purity germanium
NaI	sodium iodide
PVT	polyvinyl toluene
RH	relative humidity
SNM	special nuclear material

4. General considerations

4.1 Introduction

Unless otherwise specified in an individual step, tests enumerated in this standard may be used as part of a type test. Certain tests may be considered as acceptance tests by agreement between the user and manufacturer.

4.2 Meeting performance specifications

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

4.3 Units and measurements

For the purposes of this standard the radiological unit of exposure rate, roentgen per hour (R/h), is used. Radiation test fields may be established through measurement or calculation. Radiation test fields established by measurement shall be made using devices traceable to NIST or an equivalent recognized organization. The device used to establish radiation test fields should measure exposure rate. Conversion coefficients shall be applied (see ISO 4037-3) if using a device that measures ambient dose-equivalent rate or other dose-rate quantity. When radiation fields are determined through calculation, the technique used shall be described in the test record.

Other than ambient background, measured radiation test fields shall be determined at an uncertainty of ±20% with a coverage factor (k) of 1.

Measurement of test fields for climatic, dynamic, and electromagnetic conditions shall be made using equipment traceable to NIST or an equivalent organization.

4.4 Special word usage

The following word usage applies:

— The word *shall* signifies a mandatory requirement (where appropriate a qualifying statement is included to indicate that there be an allowable exception).

— The word *should* signifies a recommended specification or method.

— The word *may* signifies an acceptable method or an example of good practice.

4.5 Standard test conditions

Except where otherwise specified, the tests in this standard should be performed under the standard test conditions given in Table 1. The value of temperature, pressure, and relative humidity at the time of the test shall be recorded.

NOTE—Special applications, which could include a monitor's operation under weather conditions or detection needs that are not addressed by this standard, may require additional testing.

Table 1—Reference and standard test conditions

Influence quantity	Standard test conditions (unless otherwise indicated by the manufacturer)
Ambient temperature	18 °C to 25 °C
Relative humidity	≤ 75% RH
Atmospheric pressure	70 kPa to 106.6 kPa (525 mm to 800 mm of mercury at 0 °C)
Gamma background including cosmic radiation	≤ 10 μR/h
Neutron background	≤ 200 $n/s/m^2$
Electromagnetic field of external origin	Natural conditions without the presence of man-made generators
Magnetic induction of external origin	Natural conditions without the presence of man-made generators

4.6 Tests performed with variation of influence quantities

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

5. Design requirements

5.1 General characteristics

The monitors addressed by this standard detect radiological emissions from objects, containers, vehicles, or pedestrians as these items pass through the detection zone or when in the area surrounding the monitor for area monitors. Transportable and mobile monitors shall detect gamma-ray emitting radionuclides, should detect neutrons, and may identify the radionuclide(s). Transportable and mobile monitors may also have the ability to indicate the direction or location of the radiation source relative to the monitor.

The monitors shall be capable of operating independently of any peripheral device or remote station; shall be unaffected by malfunction of a peripheral device; and be powered through the use of power from the vehicle or platform, battery(s), or power generator as required.

According to their use, mobile and transportable monitors may be classified as *area*, *pedestrian*, or *vehicle* (includes rail).

When deployed on two sides of a passageway or transit way, each detection assembly should not be positioned farther apart than the applicable distance shown in Table 2. If the location of use requires distances or speeds other than those tested, additional testing should be performed to verify monitor performance.

Table 2—Setup and test parameters

Monitor type	Distance between the reference point of each detection assembly	Source to reference point distance	Dynamic speed (± 10%)	Measurement time for static testing
Area monitors	N/A	3 m	1.2 m/s	60 s
Transportable single-sided vehicle monitors	N/A	5 m	2.2 m/s (8 km/h)	60 s
Transportable multiple-sided vehicle monitors	5 m	Source centered between detection assemblies	2.2 m/s (8 km/h)	60 s
Mobile vehicle monitors	N/A	3 m	2.2 m/s (8 km/h)	60 s
Transportable pedestrian single-sided	N/A	1 m from the face of the detector	1.2 m/s	N/A
Transportable pedestrian two-sided	1 m	Centered between detection assemblies	1.2 m/s	N/A

5.1.1 Transportable pedestrian monitors

For testing purposes, the vertical height range of the detection zone shall span from 0.1 m to 2 m above the ground. Additional setup and test parameters are listed in Table 2.

5.1.2 Vehicle monitors

a) **Transportable.** For testing purposes, the vertical height range of the detection zone shall span from 0.5 m to 3.5 m above the ground or road surface. Additional setup and test parameters are listed in Table 2.

b) **Mobile.** For testing purposes, the vertical height range of the detection zone shall span from 1 m to 3 m above the ground or road surface with the detection assembly placed at the same height as it is mounted when on the mobile platform. Additional setup and test parameters are listed in Table 2.

5.1.3 Area monitors

Area radiation monitors are designed to detect increases in radiation levels in a monitored area that is adjacent to the detection assembly(s). They typically measure the ambient radiation levels and alarm when the radiation level increases to a level that is above a user-settable alarm point or a radionuclide of interest is identified. Area monitors may be used to monitor people or items moving throughout the monitored area. An area monitor may consist of multiple detection assemblies connected in such a way that each detector can operate alone or combined as a single multi-detector detection monitor.

For test purposes, an area monitor shall be tested with the source positioned adjacent to each detector assembly at a distance of 3 m and at a height of 1 m from the ground or road surface. Additional setup and test parameters are listed in Table 2.

5.2 Physical configuration

Detection assemblies mounted to vehicles or platforms may be subjected to vibration and mechanical shock environments. Special precautions should be taken to help ensure safe transit and to reduce the transmission of shock and vibration to the monitor. Mounting techniques, not addressed by this standard, need to be designed to ensure that components do not become unattached in the event of a crash.

5.3 Radiological configuration

5.3.1 Requirements

a) The monitor shall have the ability to store at least 8 h of measurement data as defined in step b).

b) The output data format from the monitor for subsequent processing or use shall meet ANSI N42.42 requirements. Each object measurement data set shall contain the following information:

   1) Manufacturer name
   2) Instrument model
   3) Serial number
   4) Software version
   5) Instrument class (e.g., mobile)
   6) Gamma detector kind (e.g., sodium iodide [NaI], Geiger Mueller tube [GMT], polyvinyl toluene [PVT])
   7) Date and time of measurement
   8) Measured background radiation levels (i.e., count rate)
   9) Measured gamma-ray radiation level (i.e., count rate)
   10) Gamma-ray alarm indication
   11) Monitor location via global positioning system (GPS) for mobile monitors
   12) Speed for mobile monitors

   If the monitor has radionuclide identification capabilities, the data file shall include the following information:

   — Unprocessed background spectrum
   — Live time and real time for the background spectrum
   — Unprocessed measured spectrum

— Live time and real time for the measured spectrum

— Energy calibration for the measured spectrum

— Radionuclide identification results

— Confidence indicator, if provided

If the monitor 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 whether the object stopped within the detection zone

c) The monitor shall have the ability to transfer each data file to an external device, such as a computer.

d) The monitor shall store photon and neutron count rate time-history data including GPS location for mobile monitors and have the ability to transfer that information to an external device, such as a computer.

5.3.2 Test method

For all requirements except for step 5.3.1.b), inspect the monitor and review the manufacturer-provided documentation to verify the requirements. Results of the verification shall be recorded.

For step 5.3.1.b):

a) Using the Table 3 ^{137}Cs source, perform a single dynamic measurement as described in 6.4 through the middle of the detection zone.

b) Open the output data file and verify that the required data are contained within the file. Validation tools may be used to perform the validation.[7]

c) Repeat steps a) and b) using the Table 3 ^{252}Cf source following guidance found in 6.5.

[7] A validation tool can be found at https://secwww.jhuapl.edu/n42/Account/LogOn.

Table 3—Test radionuclides and materials[a]

Radionuclide	Unshielded activity in µCi	Shielded activity in µCi
^{241}Am	47 (1.74 MBq)	—
^{133}Ba	10 (370 kBq)	—
^{60}Co	7 (259 kBq)	25 (925 kBq)[c]
^{137}Cs	16 (592 kBq)	85 (3.14 MBq)[c]
^{252}Cf[b]	2×10^4 n/s	—
^{67}Ga	—	94 (3.48 MBq)[d]
^{131}I	—	23 (851 kBq)[d]
^{99m}Tc	—	127 (4.7 MBq)[d]
^{201}Tl	—	88 (3.26 MBq)[d]
^{226}Ra	8 (296 kBq)	—
^{232}Th	14 (518 kBq)	—
	Fluence rate in gammas/s/cm^2	
DU	1.34 (See 6.1.7)	—
HEU	1.44 (See 6.1.7)	—
WGPu	0.40 (See 6.1.7)	—

[a] The activity and fluence rate values at the time of testing shall be within ±20% of the value shown in this table. The standard uncertainties shall be less than or equal to ±10% with a coverage factor (k) of 1 for the gamma-ray sources and neutron sources. The source activities are based on a 0.25 mm thick stainless steel encapsulation.
[b] The source is surrounded by a spherical 4 cm high-density polyethylene (HDPE) moderator.
[c] Each source is surrounded by 1 cm of steel and 8 cm (each ±10 %) of high-density polyethylene.
[d] Each source is surrounded by 8 cm (± 10%) of polymethyl methacrylate (PMMA) to represent in-vivo configurations.

5.4 Indication and alarm features

5.4.1 Requirements

External visual and audible alarm indicators, when provided, shall be designed to be tested without the use of radiation sources (e.g., lamp test). The user shall have the ability to select whether an indicator is visible or audible (e.g., lamps, beacons, or horns at the detection assembly).

Once an alarm is activated, the monitor shall be able to alarm again without the alarm being acknowledged or reset.

5.4.2 Test method

Following the manufacturer's guidance, verify that the visual and audible indicators can be tested without a radiation source, and that either visual or audible indicator can be enabled or disabled.

To verify that the monitor remains functional when in an alarm state, perform the following process:

a) Using a radiation source, cause the monitor to alarm.

b) Remove the source, but do not reset or acknowledge the alarm.

c) After a period of 10 s, reintroduce the source to cause the monitor to alarm again and verify that the alarm is indicated on the display.

d) Remove the source and acknowledge or reset the alarm.

e) Review the stored alarm files to verify that two separate alarms were recorded.

5.5 Occupancy and speed sensors for vehicle monitors

5.5.1 Requirements

When used, occupancy and speed sensors shall detect vehicle presence and estimate vehicle speed. The manufacturer shall state the minimum time required between occupancies to differentiate multiple vehicles or objects. The minimum time shall be no more than 30 s.

5.5.2 Test method

Inspect the monitor and review the manufacturer-provided documentation to verify the requirements. Functional verification is performed in 6.4. Results of the verification shall be recorded.

5.6 Markings

5.6.1 Requirements

Exterior markings on the monitor should be limited to the manufacturer's unique serial number, and 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 exterior markings of the monitor and verify that the serial number, voltage, and current requirements are shown.

b) 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 Power supply

5.7.1 Requirements

Monitors shall have the ability to operate from multiple power sources. The following list details the power supply requirements:

a) For AC, the monitor shall be able to operate from single-phase AC supply voltage of 100 V to 240 V and from 47 Hz to 63 Hz.

b) For DC, the monitor shall be able to operate from 11 V to 14.5 V (nominal 12 V).

c) Battery chargers shall meet U.S. electrical standards.

5.7.2 Test method

Inspect the monitor and review the manufacturer-provided documentation to verify the requirements. Results of the verification shall be recorded.

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 manufacturer-provided documentation to verify the requirements. Results of the verification shall be recorded.

5.9 Communications protocol

5.9.1 Requirement

Monitors shall have the ability to transfer data to an external device, such as a computer. The transfer should be achieved using a communication port that meets the requirements of Ethernet, USB, wireless, or other electronic means such as a removable media device. Consideration should be given to data security when using wireless data transfer techniques.

5.9.2 Test method

Review the information provided by the manufacturer to verify the requirement.

5.10 User interface

5.10.1 User accessible controls requirements

The trained user shall have the ability to:

a) Switch between transient (or mobile) scanning and static object measurements

b) Perform an identification and save the results, if identification is provided

c) Access stored measurement data

d) Access real-time mapping and alarm locations (for mobile monitors)

e) Transfer data files

Controls and switches shall be designed in a way to reduce accidental operation including when a user is wearing weather-protective gloves.

5.10.2 Supervisory-user accessible indications and functions requirements

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:

a) Access to and control of operating parameters (e.g., radionuclide library, integration time)

b) Access to and control of the data-logging process

c) Access to energy and/or efficiency calibration information

5.10.3 User display and visual indicators requirements

The user display shall be readable under different lighting conditions from a low ambient light level (< 150 lux) to a high ambient light level (> 10 000 lux). Displays designed to operate in an uncontrolled temperature environment shall be readable over the required temperature range (to be verified during temperature testing). Visual indicators shall include the following:

a) Gamma alarm

b) Neutron alarm, if applicable

c) Real-time response display (e.g., strip-chart, waterfall) of gamma and neutron counts

d) Stored measurement data

e) Real-time mapping with GPS data and alarm locations (for mobile monitors)

f) Radiological over-range conditions (e.g., “over-range” or “high counts”)

g) Operating mode

h) Battery lifetime, when applicable

i) Operational status (e.g., normal, calibration needed, stabilization needed)

j) Indication of source direction, if provided

If radionuclide identification capability is available, the following additional indicators shall be provided:

- Radionuclide identification result and confidence indicator, if confidence indicator is provided
- Radionuclide present but cannot be identified (e.g., "not identified," "unknown")
- Count rate is too high for radionuclide identification
- Spectral display from gamma detectors

5.10.4 Warning indicators requirements

The following warning indications shall be provided on the display as a minimum:

a) Detector failure condition

b) Energy stabilization invalid or not acceptable

c) Battery status

d) Monitor failure

5.10.5 Test method

For 5.10.1 and 5.10.2, a minimum of three personnel familiar with the use of these monitors shall review the operating instructions provided by the manufacturer and attempt to perform each of the stated requirements.

For 5.10.3 and 5.10.4, review the manual to verify that the visual and warning indicators are provided.

To verify the lighting and glove requirements, each potential user shall:

a) In an area with a low ambient light level (< 150 lux), turn on the monitor and verify that it is working properly (e.g., the battery is charged, the detector is working, self-check passed) and note any observations regarding the readability of the display.

b) Repeat step a) in an area with a high ambient light level (> 10 000 lux).

c) If the monitor has identification capabilities, perform the following steps:

   1) At normal light levels (no lux measurement requirement), move a radiation source to a position adjacent to the detection assembly while observing the display and perform a static identification of a single radionuclide (e.g., ^{137}Cs). Save the results using the process described in the manual.

   2) Repeat step 1) while wearing weather-protective gloves. Gloves worn shall be typical of those used for protection from cold temperatures.

   3) Note any observations as to how the process stated in 1) was affected by wearing gloves.

The results, including those subjective results from the three potential users, shall be recorded.

6. Radiological tests

6.1 General test method setup and execution

6.1.1 Background radiation during testing

Testing shall be performed in an area having a radiation background as defined in Table 1. The gamma-ray background intensity shall be measured prior to testing and monitored during testing using a NIST-traceable (or equivalent) 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 a spectroscopic (e.g., NaI, high-purity germanium [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 neutron background, unless it can be assured that no neutron sources are in the test area, the neutron background level should be measured using a neutron counter, neutron dosimetry, or similar device that has the ability to measure environmental neutron radiation levels.

6.1.2 Operating parameters and set up

Transportable and mobile monitors shall be set up based on the manufacturer's specifications including monitor type, e.g., area, pedestrian, or vehicle. Operating parameters such as alarm settings should remain unchanged throughout the test.

For testing purposes, the reference point is the center point of the detection assembly face or the adjacent side of the vehicle to which the detection assembly is mounted. Figure 1 shows a top view of a two-sided monitor mounted to the bed of a truck. The location of the detection assembly does not affect the height and span of the detection zone as defined in Table 2.

The monitor shall be oriented as defined by the manufacturer. If the monitor requires a background exposure rate measurement, it shall be allowed to acquire the data in a manner specified by the manufacturer prior to the start of a test.

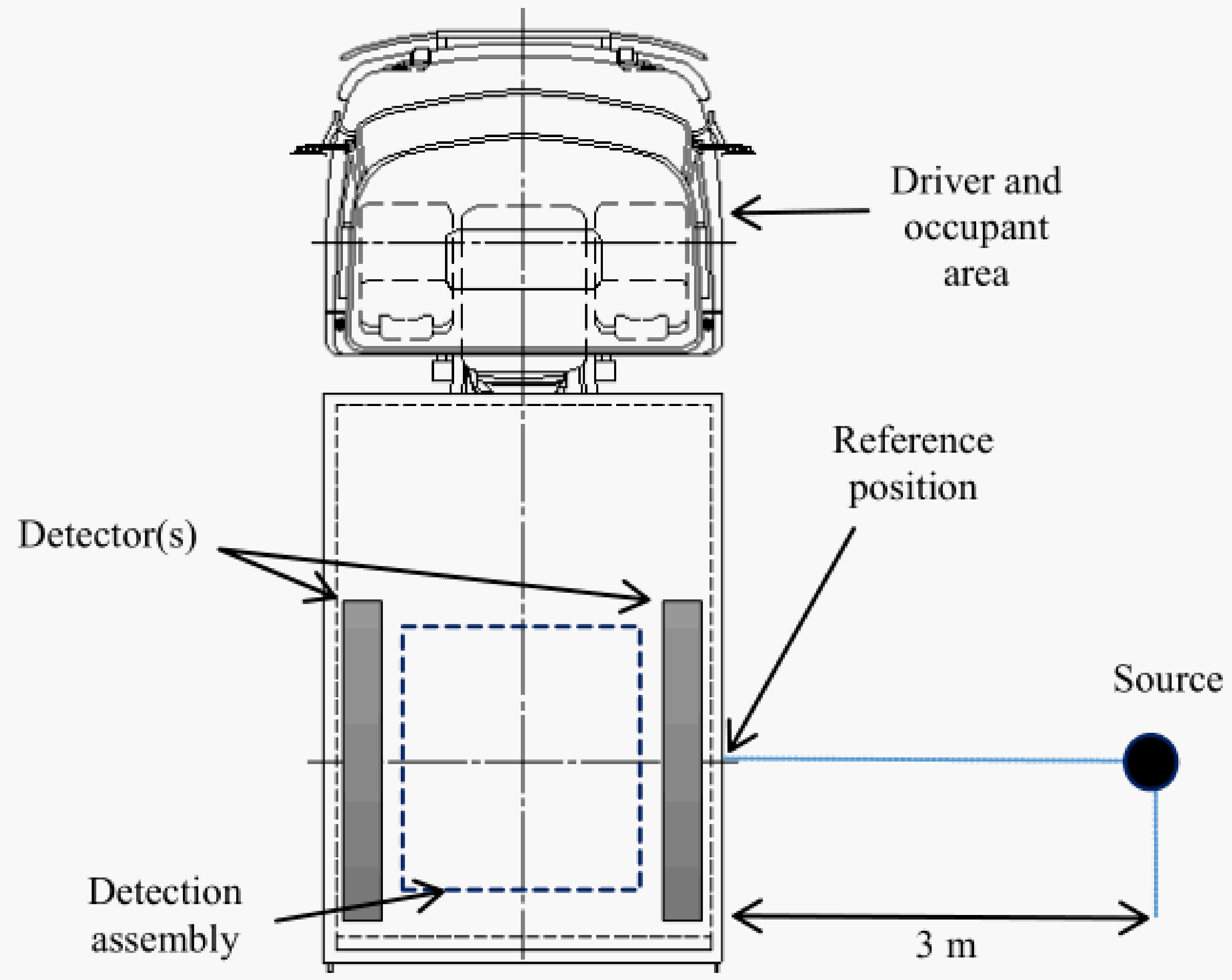

Figure 1—Reference point diagram for a two-sided mobile monitor (top-down view)

6.1.3 Evaluation distances

The setup and evaluation distances for different applications are given in Table 2.

6.1.4 Dynamic testing

Unless otherwise stated, each source shall be passed horizontally through the middle of the bottom half and the middle of the top half of the detection zone at the speed shown in Table 2. The source shall be configured such that there is 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 and as needed. 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 monitor or shielded during the delay.

6.1.5 Static testing

With the monitor not measuring radiation for detection or identification (e.g., "in standby"), place each source at the vertical center of the detection zone and at the evaluation distance, and initiate a measurement cycle for the static-measurement time shown in Table 2. The monitor's alarm shall be reset between each trial, if appropriate and as needed. Unless directed by the manufacturer, the source may remain in position between each test trial.

6.1.6 Radiation sources

All radiation sources are listed in Table 3. Activities for the unshielded gamma sources shown are based on obtaining an emission rate of 500 000 photons per second from a stainless steel (0.25 mm thick) encapsulated source using a cutoff energy of 40 keV. If a different type of encapsulation is used, the activity may need to be adjusted in order to obtain the required emission rate for the main photon energies ($\geq$ 40 keV).

^{252}Cf is the reference source for neutron alarm testing. The source shall have a neutron emission rate of 20 000 n/s ($\pm$ 20%) and, unless otherwise stated, be surrounded by a spherical 4 cm high-density polyethylene (HDPE) moderator. The inner cavity radius of the moderator should be no larger than 3 cm.

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.

6.1.7 Special nuclear material (SNM) and other mass-based radiation sources

NOTE—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.

The fluence rate stated in Table 3 for the highly enriched uranium (HEU) is based on the emission rate from an HEU sphere with a mass of approximately 237 g. The fluence rate for weapons-grade plutonium (WGPu) is based on the emission rate from a WGPu sphere having a mass of approximately 15 g and surrounded by 1 cm thick Fe. The DU fluence rate is based on the emission rate from a 2.5 kg plate with a surface area of approximately 400 cm^2 and a thickness of 0.3175 cm. Each fluence rate for gamma line specified in Table 4 was determined at a source-to-detector distance of 1 m. Test distances are shown in Table 2.

Table 4—SNM fluence rates

Material	Gamma line used for determination of fluence rate	Emission rate (gammas/s)	Fluence rate at 1 m (gammas/s/cm^2)
DU	1001 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 be used for testing as long as the required emission rate is obtained. The DU source may be assembled from available reference materials (e.g., 100 cm^2 plates). A complete description of the source including mass, form, shape, and spectrum shall be obtained as part of the test record.

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 not more than a factor of 10 greater than the 375 keV ^{239}Pu emission rate.

NOTE—The factor 10 was determined from source material measurements. For example, if the emission rate for the 375 keV line is 100 photons/s then the emission rate for the 60 keV ^{241}Am line should not exceed 1000 photons/s.

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). Use the equation below to determine the emission rates, *R*, at the 60 and 375 keV gamma-ray lines. The measurement distance shall be the same as the one used to determine the full-energy-peak efficiency of the HPGe detector.

$$R = \frac{Area_{net}}{T_{Live} \times \varepsilon(E)}$$

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)

6.2 Functionality test requirements for the environmental, electrical and electromagnetic, and mechanical performance requirements (steps 7 through 9)

6.2.1 Pre-test measurements

a) With the monitor in position for test, expose it to a gamma-ray and neutron radiation field using ^{133}Ba and ^{60}Co simultaneously, and a neutron source (when applicable). Source positions shall be marked or otherwise noted to ensure repeatability for the intermediate and post-test measurements.

b) Record 10 readings (e.g., ambient dose-equivalent rates, exposure rates, count rates) with the source(s) present.

c) Perform a series of 10 radionuclide identifications with ^{133}Ba and ^{60}Co, and record the identification results including the confidence indicators, if provided. Collect at least one spectrum from the 10-trial series. Remove the sources.

d) Calculate and record the mean, standard deviation, and coefficient of variation (COV) for the series of measurements. The COV should be less than or equal to 12% for the gamma readings. 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 radiation response acceptance range as ± 15% of the calculated mean.

6.2.2 Intermediate test measurements

a) Reposition each test source as needed.

b) Record 10 readings (e.g., ambient dose-equivalent rates, exposure rates, count rates) with the source(s) present.

c) Perform a series of 10 radionuclide identifications with ^{133}Ba and ^{60}Co, and record the identification results including the confidence indicators, if provided. Collect at least one spectrum from the 10-trial series. Remove the sources.

d) Calculate and record the mean, standard deviation, and COV for the measurement data.

6.2.3 Post-test measurements

a) Reposition each test source as needed.

b) Record 10 readings (e.g., ambient dose-equivalent rates, exposure rates, count rates) with the source(s) present.

c) Perform a series of 10 radionuclide identifications with ^{133}Ba and ^{60}Co, and record the identification results including the confidence indicators, if provided. Collect at least one spectrum from the 10-trial series. Remove the sources.

d) Calculate and record the mean, standard deviation, and COV for the measurement data.

6.3 False alarm/stability

6.3.1 Requirements

The number of false alarms or false identifications shall be less than 1 per 1000 occupancies (i.e., when an object passes through the detection zone) without a radiation source being present in the detection zone. For monitors that do not use occupancy sensors, the requirement is based on the total occupancy time plus the delay time between each object measurement or occupancy (10 s).

NOTE—This requirement is for testing only and is meant to demonstrate the stability of the monitor prior to testing. It contains two parts, radiation rate alarms and identifications that may be performed simultaneously. The requirement and associated test methods are not intended to verify the statistically based false alarm/identification rate used by the monitor (e.g., 1:10 000).

6.3.2 Test method

a) Set up the monitor in accordance with 6.1.2.

b) Perform a 10-trial dynamic test using ^{137}Cs moved through the vertical center of the detection zone and if applicable, a 10-trial neutron response test with the ^{252}Cf source moved through at the same height to verify that the monitor is functioning. Record the results.

c) Remove the radiation sources from the area.

d) If occupancy sensors are used, determine the process required to cause a 5-s occupancy for vehicle or 1-s occupancy for pedestrian monitors. The process may involve simultaneous blocking of two occupancy sensors, sequential blocking of sensors, or timed blocking of sensors. If occupancy sensors are not used, the test may be performed based on the total occupancy time for 1000 occupancies plus the delay time between each occupancy, or through the use of a track-type system as what would be used for the response to gamma and neutron radiation.

e) Perform the test using the process established in step d).

f) Observe the monitor during the test and record any alarms or identifications that may occur.

g) When complete, repeat step b) to ensure the monitor remained functional during the test.

h) The result is considered acceptable when no more than 1 alarm or false identification occurs during the performance of step e).

6.4 Response to gamma radiation

6.4.1 Requirements

A gamma alarm shall be triggered when a gamma-emitting radiation source (^{241}Am, ^{137}Cs, and ^{60}Co) at the activities given in Table 3 passes by, or is placed adjacent to, the monitor under the conditions given in Table 1 and Table 2.

NOTE—This requirement is meant to demonstrate the capability of the monitor, not to estimate detection probability and confidence in those estimates.

6.4.2 Test method

a) To verify a monitor's ability to detect moving sources (source or monitor is moving), perform the following:

   NOTE—Area monitors are addressed in step c).

   1) Set up the monitor in accordance with 6.1.2.

   2) When the monitor is operational, perform the dynamic test method (6.1.4) by passing the ^{241}Am a source from Table 3 horizontally through the middle of the bottom half of the detection zone at the speed applicable to the monitor (Table 2). Reset the alarm after the trial, if applicable.

   3) Repeat the process stated in step 2) 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 or shielded during the delay.

   4) Repeat steps 2) and 3) at the middle of the top half of the detection zone.

   5) Repeat steps 2), 3), and 4) using the ^{137}Cs source from Table 3.

6) Repeat steps 2), 3), and 4) using the ^{60}Co source from Table 3.

NOTE—Each pass is 1 trial and there are 60 trials per test height per source providing a total of 120 trials per source (60 trials for each of the 2 test heights) per radionuclide.

7) The results per radionuclide are considered acceptable when the monitor produces a gamma alarm in 117 out of 120 trials.

b) To verify a monitor's ability to detect radiation sources when the source and monitor are both stationary, perform the following:

1) Set up the monitor in accordance with 6.1.2.

2) When the monitor is operational, perform the static test method (6.1.5) using the ^{241}Am source from Table 3.

3) Repeat the process stated in step 2) for a total of 60 trials.

4) Repeat steps 2) and 3) using the ^{137}Cs source from Table 3.

5) Repeat steps 2) and 3) using the ^{60}Co source from Table 3.

6) The results per radionuclide are considered acceptable when the monitor produces a gamma alarm in 59 out of 60 trials.

c) For area monitors that are designed to provide 360° coverage, perform the following:

1) Set up the monitor in accordance with 6.1.2.

2) When the monitor is operational, perform the dynamic test method (6.1.4) by passing the ^{241}Am source from Table 3 horizontally through the vertical center of the detection zone at the evaluation distance and speed applicable to the monitor (Table 2). Reset the alarm after the trial, if applicable.

3) Repeat the process stated in step 2) 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 or shielded during the delay.

4) Repeat steps 2) and 3) using the ^{137}Cs source from Table 3.

5) Repeat steps 2) and 3) using the ^{60}Co source from Table 3.

6) Rotate the monitor or source transport system 45° and repeat steps 2), 3), 4), and 5).

7) Continue to repeat step 6) until completing a full 360°.

NOTE—Each pass is 1 trial and there are 10 trials per test angle per source providing a total of 80 trials per source.

8) The results per radionuclide are considered acceptable when the monitor produces a gamma alarm in 78 out of 80 trials.

6.5 Response to neutron radiation

6.5.1 Requirements

A neutron alarm shall be triggered when a neutron source at the activities given in Table 3 passes by the monitor under the conditions given in Table 1 and Table 2. The ^{252}Cf source shall be surrounded by a 4 cm thick spherical high-density polyethylene moderator.

6.5.2 Test method

a) Set up the monitor in accordance with step 6.1.2.

b) When the monitor is operational, perform the dynamic test method (6.1.4) by passing the moderated neutron source horizontally through the middle of the bottom half of the detection zone at the speed applicable to the monitor (Table 2). Reset the alarm after the trial, if applicable.

NOTE—Area monitors are tested with neutron source passing horizontally through the vertical center of the detection zone at the evaluation distance and speed applicable to the monitor (Table 2) using the technique described in step c) of 6.4.2.

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 or shielded during the delay.

d) Repeat steps b) and c) at the middle of the top half of the detection zone.

e) The results are considered acceptable when the monitor produces a neutron alarm in 117 out of 120 trials.

6.6 Over-range

6.6.1 Requirements

An over-range indication (e.g., "over-range", "high counts") shall be activated when the monitor is exposed to a radiation field that is greater than the manufacturer-stated maximum exposure rate.

If the over-range indication is reset or acknowledged by the user without the radiation field being reduced, a visual indication shall be provided indicating the presence of the radiation field and that the monitor 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 rate is not provided by the manufacturer, testing may not be possible.

6.6.2 Test method

a) Set up the monitor in accordance step 6.1.2.

b) When the monitor 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's stated maximum value at the surface of the adjacent detection assembly and hold the position for a period of 1 min. The monitor shall provide an "over-range" or similar indication and remain in that state until the exposure rate is reduced to the pretest level.

c) Before reducing the radiation field back to background, acknowledge or reset the audible alarm, if provided, to verify that the visual indication remains activated.

d) Remove the radiation source and measure the time required for the monitor to indicate that it is ready to function.

e) Repeat steps b) through d) two additional times for a total of 3 trials.

f) Perform a 10-trial dynamic gamma response test using ^{137}Cs only through the middle of the detection zone and a 10-trial dynamic neutron response test through the middle of the detection zone in accordance with steps 6.4 and 6.5, respectively, to verify that the monitor is functional.

g) The results are considered acceptable when the monitor provides indications as required during exposure to the over-range ^{137}Cs source, recovers within 1 min after the source is removed in each of the 3 successive trials, and functions properly after each over-range exposure.

6.7 Neutron indication in the presence of photons

6.7.1 Requirements

Gamma radiation at exposure rates up to 10 mR/h from ^{137}Cs shall not trigger the neutron alarm. The monitor shall respond as required in 6.5 to the ^{252}Cf neutron source while simultaneously exposed to the 10 mR/h field.

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, ^{99m}Tc, ^{201}Tl, and ^{67}Ga.

6.7.2 Test method

a) Set up the monitor in accordance with step 6.1.2.

b) Gamma interference test:

 1) Determine the source-to-detector distance needed to obtain 10 mR/h ± 20% (^{137}Cs) at the reference point of the detection assembly.

 2) Configure the test to move the source at the determined distance adjacent to the center of the neutron detector. The distance shall be no closer than 50 cm from the face of the detection assembly.

 3) When the monitor is operational, perform the dynamic test method (6.1.4) by passing the ^{137}Cs source horizontally through the detection zone at the determined distance from step 1) adjacent to the center of the neutron detector and at the speed applicable to the monitor (Table 2).

 4) Record the gamma and neutron detector response including alarm and maximum count rates or maximum exposure rate.

 5) Reset the alarm after the trial, if applicable.

 6) Repeat the process stated in step 3) through 5) for a total of 3 trials. There shall be a 10 s minimum delay between each trial with the source positioned at a distance where it does not affect the background or shielded during the delay.

c) Neutron indication verification:

 1) Configure the test set-up to simultaneously move the moderated ^{252}Cf source as required in step 6.5 and the ^{137}Cs source as done in step b).

 2) Repeat step b) using the step 1) source configuration.

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 while being exposed to ^{252}Cf and ^{137}Cs.

6.8 Slowly approaching source—monitor is stationary during use

6.8.1 Requirements

The monitor shall indicate when the ambient radiation background has increased to a level that is too high for it to operate as required, such as what may occur as a result of a slowly approaching radiation source.

6.8.2 Test method

a) Set up the monitor in accordance with step 6.1.2.

b) Set the dynamic test speed to 0.12 m/s for pedestrian and area, or 0.22 m/s for vehicle monitors.

c) Position the ^{137}Cs source from Table 3 at the vertical center height of the detection zone and at a lateral distance of at least 8 m from the center of the detection assembly. The distance selected is to ensure that the source does not affect the ambient background at the monitor.

d) With the monitor operational, start moving the source toward and through the middle of the detection zone at the selected speed.

e) Record the response of the monitor as the source approaches or passes through the detection zone. If the monitor 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 steps c) through e) for a total of 3 trials with a time interval of 1 min between each trial.

g) Repeat steps c) through f) using the moderated ^{252}Cf neutron source.

h) The results are considered acceptable if the monitor alarms or indicates that the background has changed for each trial.

6.9 Background effects—monitor is mobile during use

6.9.1 Requirements and background information

Mobile monitors shall function normally when exposed to changing background situations that may be encountered during normal use. The monitor shall provide a warning indication when a change in background is large enough to cause a substantial change in alarm probability, such as what may be caused when moving from different road surfaces or near different building materials.

NOTE—To help ensure that the following test method was based on realistic field conditions, measurements were obtained using different detection technologies in urban, suburban, and rural areas. The measurements were obtained with various monitors mounted in a vehicle that was driven at posted speed limits and while operated at controlled speeds. The following test method was derived from those results. The test method includes a combination of increasing and decreasing background levels while introducing a source at different times.

6.9.2 Test method

NOTE—Figure 2 and Figure 3 provide a depiction of the process stated below.

a) Determine the source-to-detector distance needed to increase the average count rate on the monitor in ambient background conditions by a factor of 3 (± 20%). The source may be ^{226}Ra, ^{232}Th, or an amount of NORM such as granite blocks, zircon sand, or fertilizer. This is the “artificial background” source.

b) Set up the mobile monitor in accordance with step 6.1.2 and allow it to start up in the normal background area.

c) Background change only:

1) With the monitor operating as it would during use (e.g., scanning), increase the count rate to the level determined in step a) using the artificial background source over a time period of 30 s by either moving the monitor or the source. The monitor should not activate any alarms during this time period. Identification of the artificial background radionuclide(s) is permitted.

2) Allow the monitor to remain in the artificial background for 2 min.

3) Following stabilization period, reduce the background over a time period of 30 s to go back to the normal background area count rate.

4) Repeat steps 1) through 3) for a total of 3 trials. No alarms should be activated or identification of radionuclides made other than those used for the artificial background source should occur during the process.

d) Background change with additional source:

1) With the monitor operating as it would during use, increase the count rate to the level determined in step a) over a time period of 30 s by either moving the monitor or the artificial background source.

2) Midway through the 30 s background change and without stopping, perform a dynamic test using ^{137}Cs through the middle of the detection zone in accordance with 6.1.4 and 6.4 and record the results.

3) Allow the monitor to remain in the artificial background for 2 min.

4) At the end of the 2-min period and without reducing the background, perform a 3-trial dynamic test using ^{137}Cs through the middle of the detection zone in accordance with 6.1.4 and 6.4 and record the results.

5) Following the 3-trial test, reduce the background over a time period of 30 s to the normal background area count rate.

6) Midway through the 30 s background change and without stopping, perform a dynamic test using ^{137}Cs through the middle of the detection zone in accordance with 6.1.4 and 6.4 and record the results.

7) Repeat steps 1) through 6) for a total of 3 trials. The monitor shall alarm for each trial when exposed to the ^{137}Cs.

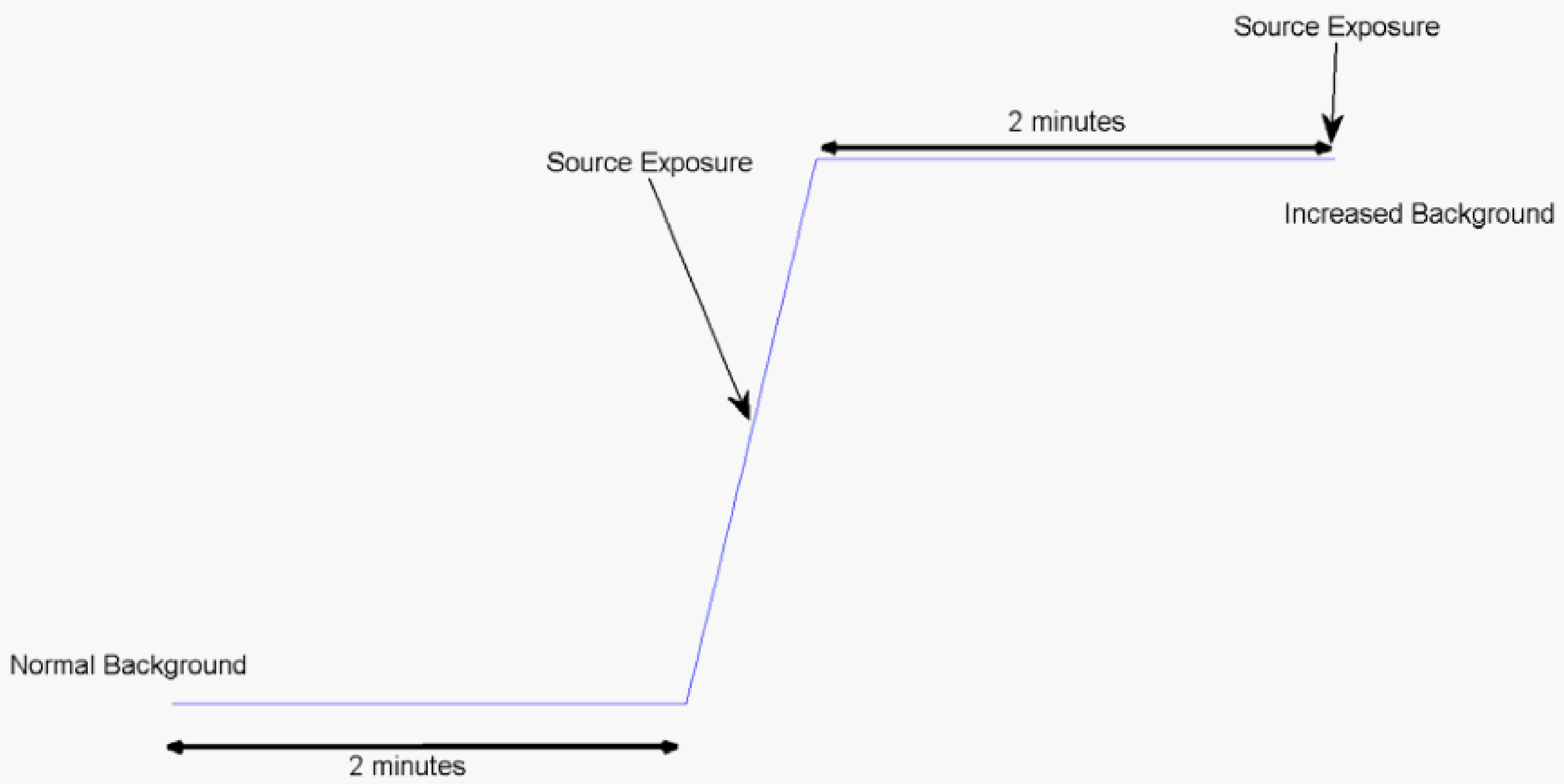

Figure 2—Increasing background with source

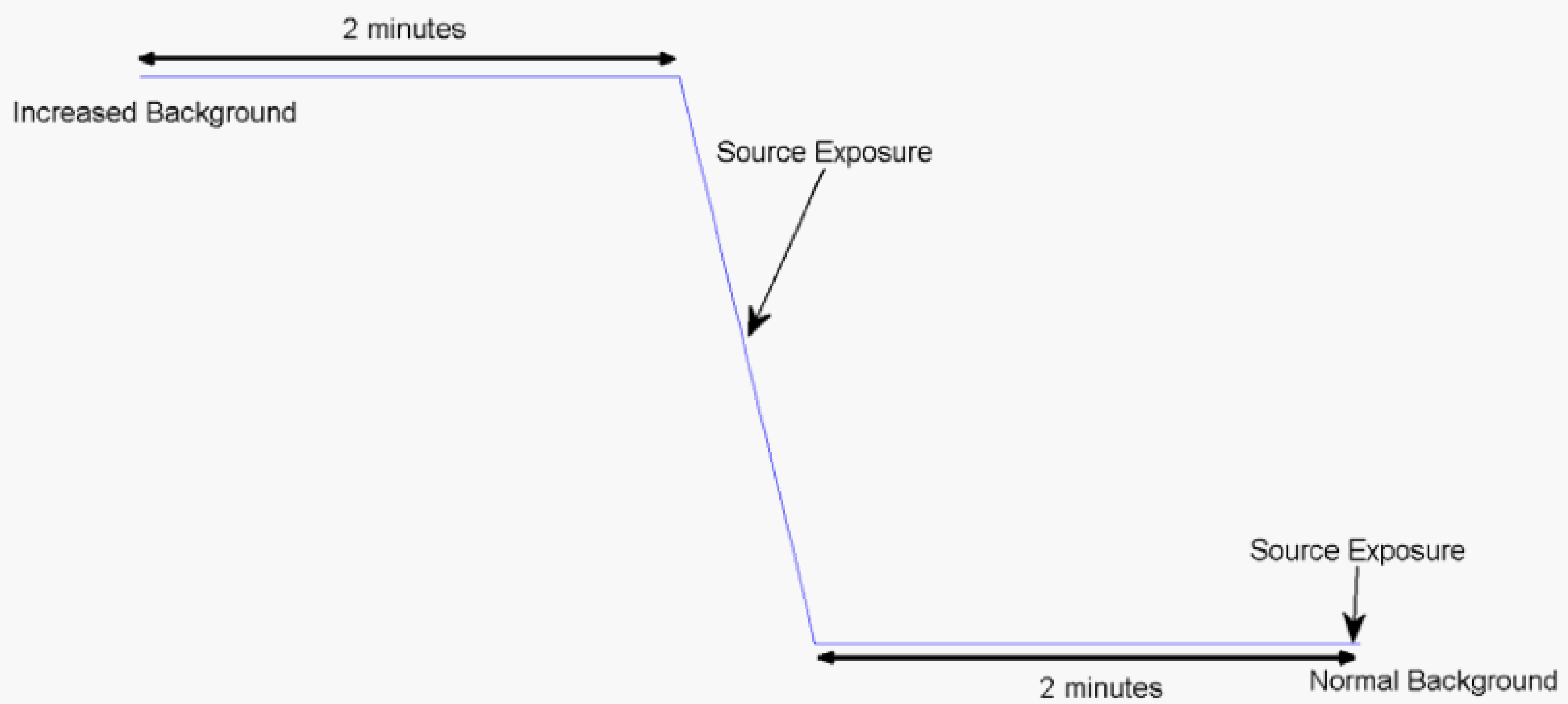

Figure 3—Decreasing background with source

6.10 Radionuclide identification—when provided

6.10.1 Radionuclide categorization

6.10.1.1 Requirement

The manufacturer shall state the radionuclides that the monitor can identify and their categories. The identification library shall contain, as a minimum, the radionuclides listed in Table 5. The categories selected should be based on IAEA Safety Guide No. RS-G-1.9 which contains a list of radionuclides and their category.

Table 5—Radionuclide library

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

6.10.1.2 Test method

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

6.11 Single radionuclide identification

6.11.1 Requirements

The monitor shall be able to identify the radionuclides and materials listed in Table 3 (except ^{252}Cf) in the dynamic (6.1.4) and static (6.1.5) modes. Shielded ^{137}Cs and ^{60}Co are used in 6.12.

6.11.2 Test method

a) Set up the monitor in accordance with step 6.1.2.

b) When the monitor is operational, perform the dynamic test method (6.1.4) by passing the ^{241}Am source from Table 3 horizontally through the middle of the bottom half of the detection zone at the speed applicable to the monitor (Table 2) and record the identification results and confidence indicator(s), if confidence indicators are provided. 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 or shielded during the delay.

d) Repeat steps b) and c) at the middle of the top half of the detection zone.

e) Repeat steps b), c), and d) using the remaining sources listed in Table 3. The medical radionuclides (^{67}Ga, ^{99m}Tc, ^{131}I, and ^{201}Tl) shall be surrounded by 8 cm (± 10%) of polymethyl methacrylate (PMMA) to represent in-vivo configurations.

f) To verify the static measurement portion of the test (6.1.5), perform the following:

   1) Per the manufacturer's instructions, set up the monitor to perform fixed-object measurements. This should require the user to perform some action to manually initiate a measurement.

   2) Position the ^{241}Am source from Table 3 at the middle of the bottom half 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), if confidence indicators are provided. Reset the alarm after the trial, if applicable.

   5) Repeat the process stated in steps 3) and 4) for a total of 10 trials without moving the source.

   6) Repeat steps 2, 3, 4, and 5 at the middle of the top half of the detection zone.

7) Repeat steps 2), 3), 4), 5), and 6) using the remaining sources listed in Table 3, except ^{252}Cf. The medical radionuclides (^{67}Ga, ^{99m}Tc, ^{131}I, and ^{201}Tl) shall be surrounded by 8 cm (± 10%) PMMA to represent in-vivo configurations.

g) The performance is considered acceptable when the identification results are complete and correct in 19 out of 20 consecutive dynamic and static trials for each radionuclide. Twenty trials combine the results from each test height. See Annex A and Annex B for information regarding the analysis process.

6.12 Identification of shielded radionuclides

6.12.1 Requirements based on shielding related to shipping containers

A monitor 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 3 surrounded by 1 cm of steel and 8 cm (± 10%) of HDPE. The steel and HDPE represent mixed shielding materials (low Z to high Z) that could surround a source.

NOTE—There are no pass/fail criteria associated with this step.

6.12.2 Test method

a) Set up the monitor in accordance with step 6.1.2.

b) When the monitor is operational, perform the dynamic test method (6.1.4) by passing the shielded-activity Table 3 ^{137}Cs source horizontally through the middle of the detection zone at the speed applicable to the monitor (Table 2) and record the identification results and confidence indicator(s), if provided. 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 or shielded during the delay.

d) Repeat steps b) and c) using the shielded-activity Table 3 ^{60}Co source.

e) For the static measurement portion of the test (6.1.5), perform the following:

1) Per the manufacturer's instructions, set up the monitor to perform fixed-object measurements. This should require the user to perform some action to manually initiate a measurement.

2) Position the shielded-activity Table 3 ^{137}Cs source assembly at the middle of the detection zone 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 3) and 4) for a total of 10 trials without moving the source.

6) Repeat steps 2), 3), 4), and 5) using the shielded-activity Table 3 ^{60}Co source assembly.

6.13 Simultaneous radionuclide identification

6.13.1 Requirement

Mobile and transportable monitors shall have the ability to identify more than one radionuclide simultaneously. This requirement is verified using the source combinations shown in the test method, 6.13.2.

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

6.13.2 Test method

a) Set up the monitor in accordance with step 6.1.2.

b) Prepare to perform the test using the following source combinations:

— ^{137}Cs + DU

— ^{99m}Tc + HEU

— ^{131}I + WGPu

— NORM + HEU

Other than NORM, each source shall be at the activity and configuration stated in Table 3. As part of the test-preparation process, measure and record the exposure rate from each source configuration at a distance of 50 cm from the center of the source configuration. The sources shall be configured such that no source shields the other.

c) When the monitor is operational, pass a source combination horizontally through the middle of the detection zone using the dynamic test method (6.1.4) and at the speed applicable to the monitor (Table 2).

d) Record the identification results and the confidence indicator(s), if provided. Reset the alarm after the trial, if applicable.

e) Repeat the process stated in steps c) and d) for a total of 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 or shielded during the delay.

f) Repeat steps c) through e) for each source combination, except for the NORM combination.

g) To verify the static measurement portion of the test (6.1.5), perform the following:

1) Per the manufacturer's instructions, set up the monitor to perform fixed-object measurements. This should require the user to perform some action to manually initiate a measurement.

2) Position a source combination at the middle 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 steps 3) and 4) for a total of 10 trials without moving the source combination.

6) Repeat steps 2) through 5) for each source combination, except for the NORM + HEU.

h) To verify the requirement utilizing NORM, 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 3 with 9 cm of PMMA. The sources shall be configured such that neither source shields the other.

   2) To replicate the existence of the 1460 keV photo peak that may be present in NORM found in commerce, co-locate the NORM + HEU source combination with 25 kg of KCl.

   3) Position the HEU source at the distance determined when performing the process described in step 6.11.2.

   4) Repeat steps c) through e), and g) using the NORM surrogate configuration and HEU. Alternative methods to move the NORM surrogate material through the detection zone may be used.

i) Record the number of complete and correct identifications (see Annex A and Annex B 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.

6.14 Radionuclide not in library

6.14.1 Requirements

A monitor 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.

6.14.2 Test method

a) Select a radionuclide from Table 3. A single energy or simple spectrum source is recommended (e.g., ^{137}Cs).

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 monitor in accordance with Table 2.

d) When the monitor is operational, perform the dynamic test (6.1.4) 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), if provided. Reset the alarm after the trial, if applicable.

e) Repeat the process stated in step d) 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, or shielded during the delay.

f) To verify the static measurement portion of the test (6.1.5), perform the following:

   1) Per the manufacturer’s instructions, set up the monitor to perform fixed-object measurements. This should require the user to perform some action to manually initiate a measurement.

   2) Position the test source at the middle 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), if provided. Reset the alarm after the trial, if applicable.

5) Repeat the process stated in steps 3 and 4 for a total of 10 trials without removing the source from the detection zone.

g) The results are considered acceptable if the response from each trial meets the stated indication requirements.

7. Environmental (climatic) performance requirements

7.1 General

Monitors shall comply with IEC 62706 concerning the ambient temperature, relative humidity, and other metrological requirements for mobile or transportable instrumentation. To ensure that each requirement is met, ^{133}Ba and ^{60}Co are used for the gamma detector and a neutron source, e.g., ^{252}Cf, is used for the neutron detector.

It is acceptable, but not recommended, to test the monitor by testing components only, such as detector(s) and controller. Portions of the monitor that are not intended for uncontrolled environments or that do not affect the radiological response of the monitor, such as the trailer or powered vehicle, may be excluded from this test. Cooling or heating systems that are part of the monitor shall be tested together with the detection assembly.

7.2 Ambient temperature

7.2.1 Requirement

Over the temperature range specified in IEC 62706 for mobile or transportable monitors (–30 °C to +55 °C), the mobile monitor shall function correctly including monitoring for changes in radiation levels, performing identifications, and responding to neutron sources (when applicable). There shall be no visible external damage to the instrument and all control functions shall be verified to be operating correctly.

The manufacturer shall state the temperature range for displays or user interface components intended for use in weather protected locations.

7.2.2 Test method

Set up the temperature-test system as stated in IEC 60068-2-1 and 60068-2-2, respectively. Follow the ambient temperature method of test specified in IEC 62706.

NOTE—For this test, an external power supply may be used to power the instrument ensuring that it remains on for the duration of the test.

To verify the performance of the monitor against the requirements, perform the pre-test measurements as described in 6.2.1. During the test, observe the monitor for changes in functionality using the functionality verification test found in Table 6, and perform the intermediate measurements as described in 6.2.2 at −20 °C, −10 °C, 0 °C, 10 °C, 30 °C, and 40 °C after a 2 h soak at each temperature, as well as at the low and high temperature extremes at the beginning, middle, and end of the 16 h soak. The temperature test shall be performed from –30 °C to +55 °C, then back to the nominal temperature at temperature change rates of 10 °C/h.

Following return to the nominal temperature, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6.

Table 6—Test result analysis

Verification test	Analysis technique
Functionality	The results are acceptable if there are no unexpected alarms or fault indications during the test.
Identification results	The identification results are acceptable if the complete and correct results at each test point from each series of identifications are the same as or better than the identification results obtained prior to the test. For example, if the 10-trial results prior to a test are complete and correct in 6 out of 10 trials, the complete and correct results at each test point shall be 6 or more.
Radiation response	The mean response at each test point shall be within the acceptance range and the COV should be less than 12%.

7.3 Relative humidity

7.3.1 Requirement

Over the range of relative humidity specified in IEC 62706 for mobile and transportable monitors (40% to 93% at 35 °C), the monitor shall function correctly including monitoring for changes in radiation levels, performing identifications, and responding to neutron sources (when applicable).

There shall be no visible external damage to the monitor, and all control functions shall be verified to be operating correctly.

7.3.2 Test method

Set up the temperature/humidity test system as stated in IEC 60068-2-66, and follow the relative humidity method of test specified in IEC 62706.

To verify the performance of the monitor against the requirements, perform the pre-test measurements as described in 6.2.1. During the test, observe the monitor for changes in functionality using the functionality verification test found in Table 6, and perform the intermediate measurements as described in 6.2.2 at the beginning, middle, and end of the 16 h high-humidity soak.

Following return to the nominal temperature and humidity, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6.

7.4 Moisture and dust protection

7.4.1 Requirement

Components designed for use in an unprotected environment (i.e., external to a vehicle) shall be designed to meet the IP classification requirements stated in IEC 62706 for non-weather protected mobile monitors (IP 54). Components mounted inside or outside of a vehicle shall meet the dust requirement.

7.4.2 Test method—dust

Set up the dust system and mobile monitor components (device under test) as defined in IEC 60068-2-68. The test shall be performed based on La2 using a duration of 1 h.

To verify the performance of the components against the requirements, perform the pre-test measurements as described in 6.2.1 prior to the exposure dust. Following exposure to the dust environment, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6. For this test, also inspect the unit to determine the extent of dust ingress. Particular attention shall be made to enclosed compartments and easily accessed portions of the mobile monitor components that were tested.

7.4.3 Test method—moisture

NOTE—The moisture requirement is only applicable to monitors or components mounted to the outside of a vehicle.

Set up the moisture system and mobile monitor components (device under test) as defined in IEC 60529. Additional information is available in IEC 60068-2-18. The water exposure shall be performed in accordance with test Rb 2 using a 6.3 mm nozzle at a flow rate of 12.5 l/min ± 5%. The test duration shall be 1 min per m^2 calculated based on the surface area being exposed at a minimum duration of 3 min.

To verify the performance of the mobile monitor against the requirements, perform the pre-test measurements as described in 6.2.1. Observe the response of the mobile monitor while being exposed to the water spray and record any functional changes that may occur (e.g., alarms, fault indications). Following exposure to the moisture environment, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6. For this test, also inspect the unit to determine the extent of moisture ingress. Particular attention shall be made to any enclosed compartments and easily accessed portions of the components under test.

For testing against salt water spray, the mobile monitor shall meet the same moisture performance requirements after being subjected to a salt water spray as defined in 60068-2-11 using a conditioning duration of 16 h.

8. Electrical and electromagnetic performance requirements

8.1 Power supply

8.1.1 Requirement

Line-powered monitors 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 and the requirement is considered met when the manufacturer provides evidence that only compliant power supply(s) are used.

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 monitor and power up the monitor.

b) Perform the pre-test measurements as described in 6.2.1.

c) Increase the supply voltage to 12% above the nominal value and perform the intermediate measurements as described in 6.2.2.

d) Decrease the supply voltage to 12% below the nominal value and perform the intermediate measurements as described in 6.2.2.

e) Repeat step c) at the nominal supply voltage with the line frequency at 3% above and then 3% below the nominal frequency (58 Hz to 62 Hz).

f) Following return to nominal voltage and frequency, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6.

8.2 Radio frequency (RF)

8.2.1 Requirement

Mobile and transportable monitors should not be affected by RF fields in accordance with the radio frequency-immunity requirements for all other instrument types as defined in IEC 62706 with the following changes:

— Frequency range from 80 MHz to 2500 MHz at field intensities of 10 volts per meter (V/m) from 80 MHz to 1000 MHz and 3 V/m from 1000 MHz to 2500 MHz.

NOTE—Wireless interface technologies may not function properly in the presence of RF.

8.2.2 Test method

An alternative test method may be used. When used, the alternative method shall be described.

Set up the test conditions in accordance with IEC 61000-4-3 and use the method of test defined in IEC 62706. The monitor should be configured as it would be used during operation. If the monitor is mounted in a vehicle, the monitor should be mounted using the same technique including wiring and any enclosures and grounding techniques. Stands or other supports shall be used when necessary to reduce accidental grounding of the monitor. Although polystyrene is not recommended for use when testing with neutrons, it is permitted and recommended for RF testing since the ionizing radiation response from testing is relative to the ionizing radiation response with the RF field present.

To verify the performance of the mobile monitor against the requirements, perform the pre-test measurements as described in 6.2.1. Without moving the radiation test sources, observe the response of the mobile monitor while being exposed to the radio frequency conditions and record any functional changes that may occur (e.g., fault indications). Remove the radiation test sources and repeat the radio frequency exposure while observing the response of the radionuclide identification device (RID). Record any functional changes that may occur (e.g., alarms, fault indications).

Following the completion of the test, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6.

8.3 Radiated emissions

8.3.1 Requirement

The electromagnetic (EM) fields emitted by the mobile or transportable monitor at 3 m shall be less than what is shown in Table 7 in accordance with IEC 62706.

Table 7—Emission frequency range

Emission frequency range (MHz)	Field strength (microvolts/meter) at 3 m
30 to 88	100
88 to 216	150
216 to 960	200
>960	500

8.3.2 Test method

a) Place the monitor in an area with a low and controllable radio frequency environment (e.g., anechoic chamber).

b) Position an antenna from 1 m to 3 m from the reference position (shown in Figure 1 for mobile-mounted systems). The emission limits require correction if distances other than 3 m are used.

c) With the monitor off, collect a background RF spectrum using a scanning bandwidth of 120 kHz (typical bandwidth for commercial emissions standards, i.e., FCC Part 15 and the various CISPR specifications).

d) Switch the monitor on.

e) Once the monitor is operational, perform an RF scan with the antenna in the vertical orientation. Rotate the monitor (or move the antenna) as needed to ensure that each side is measured for emissions.

f) Using the peak-detection method, record emissions that are greater than the values stated in Table 7 corrected as needed based on the antenna distance used.

g) If no RF emissions are recorded, proceed to step h). If observed RF emissions are greater than the values stated in Table 7, additional testing is not required.

h) Rotate the antenna to the horizontal orientation and repeat steps e) and f).

8.4 Battery lifetime

8.4.1 Requirement

Transportable or mobile monitors that use battery power shall be able to operate, including storing measurement data, for up to 8 h if there is a loss of external power.

8.4.2 Test method

a) The monitor shall be placed under standard test conditions, switched on, and allowed a stabilization and background-detection period as specified by the manufacturer.

b) Disconnect the AC line, as appropriate, and using only ^{137}Cs, perform a dynamic measurements at 30 min intervals with the source passing through the mid-point of the detection zone. Perform the test for 8 h.

c) To be acceptable, the transportable or mobile monitor shall function for the entire 8 h period and shall have stored all the required information from each occupancy. The low-battery indication shall not have activated during the 8 h period.

8.5 Electrostatic discharge (ESD)

8.5.1 Requirement

Mobile and transportable monitors shall not be affected by exposure to electrostatic discharges at intensities of up to 6 kV using the contact discharge technique in accordance with the electrostatic requirements defined in IEC 62706.

8.5.2 Test method

Set up the test conditions in accordance with IEC 61000-4-2 and use the method of test defined in IEC 62706 for battery-powered or non-installed instruments. Discuss the test including setup and electrostatic discharge exposure levels with the manufacturer to establish three appropriate discharge points. Discharge points should be selected based on user accessibility (e.g., monitor frame, detector enclosures, and maintenance access points).

To verify the performance of the monitor against the requirements, perform the pre-test measurements as described in 6.2.1. Observe the response of the monitor without radiation sources present while being exposed to the discharges and record any functional changes that may occur (e.g., alarms, fault indications). Following the exposure, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6.

9. Mechanical (dynamic) performance requirements

9.1 General

Mobile and transportable monitors shall comply with IEC 62706 concerning the mechanical requirements for mobile or non-installed instrumentation.

9.2 Microphonics/impact

9.2.1 Requirement

Mobile and transportable monitor components shall be unaffected by microphonic conditions such as those that may occur from low-intensity impacts from sharp contact with hard surfaces in accordance with the microphonic/impact requirements for all other devices defined in IEC 62706 (1.0 J).

9.2.2 Test method

Follow the method of test defined in IEC 62706.

To verify the performance of the mobile monitor against the requirements, perform the pre-test measurements as described in 6.2.1. Observe the response of the mobile monitor without radiation sources present while being exposed to the impacts and record any functional changes that may occur (e.g., alarms, fault indications). Following the test, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6.

9.3 Vibration

9.3.1 Requirement—stationary operations

Mobile and transportable monitors shall withstand exposure to vibrations associated with the operation of mobile monitors as defined in IEC 62706.

9.3.2 Test method—stationary operations

Set up the vibration system and mobile or transportable monitor components (device under test) as defined in IEC 60068-2-64. The test specifics are defined in IEC 62706.

To verify the performance of the mobile monitor against the requirements, perform the pre-test measurements as described in 6.2.1. Switch the monitor off and expose it to the vibration for a period of 1 h. Following vibration, switch the monitor on and perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6. In addition, inspect the exposed components to ensure that the physical condition was not affected by the shocks (e.g., solder joints shall hold; nuts and bolts shall not come loose).

9.3.3 Requirement—mobile operations

Mobile monitors shall function normally during exposure to vibrations associated with mobile monitors as defined in IEC 62706.

9.3.4 Test method

Set up the vibration system and mobile monitor components (device under test) as defined in IEC 60068-2-64. The test specifics are defined in IEC 62706.

To verify the performance of the mobile monitor against the requirements, perform the pre-test measurements as described in 6.2.1. With the monitor operating, expose it to the vibration for a period of 1 h and observe the response of the mobile monitor without radiation sources present while being exposed to the vibration and record any functional changes that may occur (e.g., alarms, fault indications). Just prior to the end of the vibration exposure, perform the intermediate measurements as described in 6.2.2. Following vibration, perform the post-test measurements as described in 6.2.3, and analyze the results in accordance with Table 6. In addition, inspect the exposed components to ensure that the physical condition was not affected by the vibration exposure (e.g., solder joints shall hold; nuts and bolts shall not come loose).

10. Documentation

10.1 Report

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

a) Contact information for the manufacturer including name, address, telephone number, fax number, e-mail address, etc.

b) Type of monitor, detector, and types of radiation the monitor is designed to measure

c) Power supply requirements

d) Recommended operational parameters such as: detector response, false alarm probability, alarm thresholds, operating parameters, and radionuclide libraries

e) Static measurement time

f) Size of the detection zone

g) Complete description of the evaluated monitor

h) Description of the occupancy sensors and the occupancy process, when applicable

i) Enclosure specification classification

j) Inclusion of any hazardous material that may require additional regulation (such as radionuclide check source, pressurized gases, corrosive materials)

k) List of radionuclides that are identified by the monitor

l) Description of the confidence-level indication

m) Over-range exposure rate values for gross counting and identification

10.2 Operation and maintenance manual

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

a) Operating instructions and restrictions

b) Module connection schematic

c) Electrical connection schematic

d) Mounting instructions

e) Spare parts list

f) Troubleshooting guide

g) Description and protocol for communication methods of transmitting and receiving data

Annex A

(informative)

Uranium/plutonium detection and identification guidance

Table A.1—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 ^{234m}Pa being short-lived daughters of ^{238}U are still present)	U, or $^{235}U + ^{238}U$	There is no practical way for this application to distinguish refined U from slightly enriched U. Because of this, refined U should be categorized as special nuclear material (SNM).
Low-enriched uranium (LEU)	Enriched U up to a ^{235}U concentration of 20% ^{235}U.	U, LEU, ^{235}U, or $^{235}U + ^{238}U$	May include a sub-class that could indicate slightly enriched uranium U enriched to a ^{235}U concentration of 0.9% to 2%.
High-enriched uranium (HEU)	Enriched U up to a ^{235}U concentration at higher than 20% ^{235}U	U, HEU, ^{235}U, or $^{235}U + ^{238}U$	
Depleted uranium (DU)	U with lower than natural abundance of ^{235}U	U, DU, $^{235}U + ^{238}U$, or ^{238}U	Although DU is not typically considered a SNM, DU may sometimes 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.
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.
RGPu	Primarily ^{239}Pu with approximately 15% ^{240}Pu	^{239}Pu, RGPu	RGPu contains ^{241}Am and the same radionuclides as WGPu.
^{238}Pu	approximately 90% $^{240}Pu + ^{238}Pu$	^{238}Pu, ^{240}Pu	Radioisotope thermal generators use these radionuclides. Unlikely to be encountered by a monitor. Likely neutron alarm is primary signature of Pu-240.

Annex B

(informative)

Guidance regarding identification performance

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

B.1 Complete and correct (C&C)

Source “X” identified as “X”.

Sources “X + Y” identified as “X + Y”.

For example:

a) $^{235}U \rightarrow {}^{235}U$

a) $^{235}U \rightarrow {}^{235}U + {}^{40}K$

b) $^{235}U \rightarrow {}^{235}U + {}^{40}K + Th$

c) $^{235}U \rightarrow {}^{235}U + {}^{40}K + Th + Ra$

d) $^{235}U + {}^{67}Ga \rightarrow {}^{235}U + {}^{67}Ga + {}^{40}K + Th + Ra$

“Y” includes daughters that may be present. See Table B.1 for a list of daughters and possible impurities.

B.2 Incomplete

Source “X + Y” identified as “X” or “Y”.

For example:

— $^{235}U + {}^{226}Ra \rightarrow {}^{226}Ra$

B.3 Incorrect

Source “X” identified as “X + Y”.

For example:

— $^{235}U \rightarrow {}^{235}U + {}^{237}Np$

— $^{67}Ga \rightarrow {}^{235}U + {}^{67}Ga$

B.4 Incomplete and incorrect (I&I)

Source "X" being identified as "Y".

Source "X + Y" identified as "A + B".

For example:

— $^{235}U \rightarrow {}^{67}Ga$

— $^{235}U + {}^{137}Cs \rightarrow {}^{99m}Tc + {}^{133}Ba$

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 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 understood.

Table B.1—Radionuclide daughters and impurites

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, ^{234m}Pa
^{99m}Tc	^{99}Mo
^{232}Th	^{228}Th, ^{232}U
^{226}Ra	^{214}Bi, ^{214}Pb

Consensus

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