



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

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**Accredited by the American National Standards Institute**

Sponsored by the  
National Committee on Radiation Instrumentation, N42

N42.43

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IEEE  
3 Park Avenue  
New York, NY 10016-5997, USA

23 April 2007

**ANSI N42.43-2006**



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

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**National Committee on Radiation Instrumentation, N42**

Accredited by the  
**American National Standards Institute**

Secretariat  
**Institute of Electrical and Electronics Engineers, Inc.**

Approved 12 December 2006  
**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 systems that are typically in operation on a platform that is in motion. This standard also addresses radiation detection systems that can be carried on a person such as backpack-type systems.

**Keywords:** mobile radiation monitors, transportable radiation monitors

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Print: ISBN 0-7381-5562-4                      SH95639  
PDF: ISBN 0-7381-5563-2                      SS95639

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## Introduction

This introduction is not part of ANSI N42.43, 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 of September–October 2006.

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<i>Organization Represented</i> .....	<i>Name of Representative</i>
Bartlett Services .....	Morgan Cox
Canberra .....	Markku Koskelo
Chew, M.H .....	Jack M. Selby
Commerce Dept, U.S. NIST .....	Michael P. Unterweger
.....	Louis Costrell ( <i>Alt.</i> )
Consultant .....	Frank X. Masse
Department of Homeland Security .....	Peter Shebell
Entergy-ANO .....	Ron Schwartz
Health Physics Society .....	Sandy Perle
IEEE .....	Louis Costrell
.....	Julian Forster ( <i>Alt.</i> )
.....	Anthony Spurgin ( <i>Alt.</i> )
.....	Michael P. Unterweger ( <i>Alt.</i> )
International Medcom .....	Don Sythe
Lawrence Berkeley National Lab .....	Edward J. Lampo
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NASA, GSFC .....	Sachidananda R. Babu
Nuclear Regulatory Commission .....	Cynthia Jones
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ORNL .....	Peter J. Chiaro, Jr.
.....	Charles Britton ( <i>Alt.</i> )
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Swinth Associates .....	Kenneth L. Swinth
U.S. Army .....	Edward Groeber
Members-At-Large .....	Ernesto Corte
.....	Joseph C. McDonald
.....	Paul L. Phelps
.....	Joseph Stencil
.....	Lee J. Wagner

At the time this standard was completed, Subcommittee N42.HSI had the following membership:

**Morgan Cox**, *Co-Chair*

**Michael P. Unterweger**, *Co-Chair*

Paul Bailey  
Peter J. Chiaro, Jr.  
David Gilliam  
Mark D. Hoover

Cynthia G. Jones  
Ronald Keyser  
Richard Kouzes  
Joseph C. McDonald

Leticia Pibida  
Brian Rees  
Peter Shebell  
David Trombino

At the time this standard was completed, the ANSI N42.43 Working Group had the following membership:

**Peter J. Chiaro**, *Chair and project leader*

Robert August  
Sharon Bailey  
Morgan Cox  
Carl J. Czajkowski  
Rebecca Detwiler  
Gerard Garino

Adam Hutter  
Randy Jones  
Gene Kallenbach  
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Michael P. Unterweger  
Robert Whitlock

# Contents

1. Overview .....	1
1.1 Scope .....	1
1.2 Purpose .....	2
2. Normative references.....	2
3. Definitions .....	4
3.1 General .....	4
3.2 Definitions of particular relevance to ANSI N42.43 .....	7
4. General considerations .....	8
4.1 Evaluation of monitors .....	8
4.2 Meeting performance specifications.....	9
4.3 Units and uncertainties .....	9
4.4 Special word usage .....	9
4.5 Standard test conditions.....	9
4.6 Tests performed under standard test conditions.....	10
4.7 Tests performed with variation of influence quantities .....	10
4.8 Statistical fluctuations.....	10
5. Design requirements.....	11
5.1 General characteristics.....	11
5.2 Physical configuration .....	14
5.3 Data storage .....	15
5.4 Indication features .....	15
5.5 Occupancy and speed sensors for vehicle monitors.....	16
5.6 Markings.....	16
5.7 Power supply .....	16
5.8 Protection of switches.....	17
5.9 Effective range of measurement .....	17
5.10 Software and data analysis.....	17
5.11 Operating parameters.....	18
6. Radiological tests.....	19
6.1 General .....	19
6.2 Speed of moving sources or mobile system.....	19
6.3 Evaluation distances .....	19
6.4 Fixed object tests .....	19
6.5 Detector response .....	20
6.6 Reference gamma radiation .....	21
6.7 False alarm test .....	21
6.8 Detector response to gamma radiation.....	21
6.9 Detector response to neutron radiation .....	22
6.10 Overload test.....	23
6.11 Neutron indication in the presence of photons.....	23
6.12 Background effects—monitor is stationary during use.....	24
6.13 Background effects—monitor is mobile during use .....	24

6.14 Radionuclide identification—when provided .....	26
6.15 Determination of full-energy-peak efficiency .....	29
6.16 Determination of full width-half maximum (FWHM) (spectroscopic monitors only) .....	30
7. Environmental performance requirements .....	30
7.1 Ambient temperature .....	30
7.2 Relative humidity .....	32
7.3 Moisture and dust protection .....	33
8. Electrical and electromagnetic performance requirements .....	34
8.1 Radio frequency (RF) .....	34
8.2 Radiated emissions .....	34
8.3 AC line voltage operation .....	35
8.4 Battery life-time .....	35
8.5 Electrostatic discharge (ESD) .....	36
8.6 Conducted disturbances induced by bursts and radio frequencies .....	36
8.7 Surges and oscillatory waves .....	37
9. Mechanical performance requirements .....	37
9.1 Microphonics/impact .....	37
9.2 Vibration .....	37
9.3 Mechanical shock .....	38
10. Documentation .....	39
10.1 Type test report .....	39
10.2 Certification .....	39
10.3 Operation and maintenance manual .....	40
Annex A (informative) Diagram of mounting dimensions for Radionuclide Identifying Portal Monitors ..	41



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

## 1. Overview

### 1.1 Scope

This standard specifies the operational and performance requirements for transportable and/or mobile radiation monitors used in homeland security applications. 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. Transportable monitors may be mounted to a vehicle such as a trailer, and are only used when the vehicle is stationary. Mobile monitors are those systems that are typically in operation on a platform that is in motion but that can also be used while stationary. These monitors may be mounted in vehicles, including water craft, towed systems, or those monitors mounted to cranes. Mobile monitors can also be those that are used while being carried by a person such as a backpack.

Operational requirements established by this standard include radiation detection and radionuclide identification (if used), 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 ensure that a monitor meets the requirements stated. Successful completion of the radiation tests described in this standard should not be construed as an ability to successfully detect and identify all radionuclides in all environments.

Other than backpack units, this standard does not cover instruments that are hand-carried during use, or those instruments addressed by ANSI N42.32, ANSI N42.33, ANSI N42.34, ANSI N42.35, and ANSI N42.38.<sup>1</sup>

This standard addresses instruments used within the United States, but can be used as a basis for use elsewhere.

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<sup>1</sup> 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/>). For more information on references, see Clause 2.

## 1.2 Purpose

This standard specifies the performance criteria and tests for transportable and/or mobile radiation monitors used for homeland security.

## 2. Normative references

The following referenced documents are indispensable for the application of this document. 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 N42.22, American National Standard—Traceability of Radioactive Sources to the National Institute of Standards and Technology (NIST) and Associated Instrument Quality Control.<sup>2</sup>

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

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

Bureau National de Métrologie-Laboratoire National Henri Becquerel/Commissariat à l'énergie atomique (BNM-LNHB/CEA).<sup>3</sup>

EIA RS-232-C, Interface between Data Terminal Equipment and Data Communication Equipment Employing Serial Data Exchange.<sup>4</sup>

EIA 485, Specification of a Two-Wire, Half-Duplex, Multipoint Serial Connection.

Evaluated Nuclear Structure Data File [ENSDF, National Nuclear Data Center (NNDC)].<sup>5</sup>

FCC Rules, Code of Federal Regulations, Title 47, Part 15, Radio Frequency Devices.<sup>6</sup>

IAEA, "Code of Conduct on the Safety and Security of Radioactive Sources, Table 1, 2004".<sup>7</sup>

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

IEC 60050-393 {Ed.2.0}, International Electrotechnical Vocabulary—Part 393: Nuclear instrumentation: Physical phenomena and basic concepts.<sup>8</sup>

IEC 60050-394 {Ed.2.0}, International Electrotechnical Vocabulary—Chapter 394: Nuclear instrumentation: Instruments.

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<sup>2</sup> 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/>).

<sup>3</sup> Commissariat à l'Énergie Atomique (CEA) Saclay., 91191 Gif-sur-Yvette, France.

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

<sup>5</sup> See <http://www3.nndc.bnl.gov/ensdf> for more information.

<sup>6</sup> CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (<http://www.access.gpo.gov/>).

<sup>7</sup> IAEA publications are available from the International Atomic Energy Agency, P.O. Box 100, Wagner Strasse 5, A-1400 Vienna, Austria (<http://www.iaea.org>).

<sup>8</sup> IEC publications are available from the Sales Department of 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 Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA(<http://www.ansi.org>).

IEC 60068-2, Environmental Testing—Part 2: Tests.

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, Electromagnetic compatibility (EMC), Testing and measurement techniques.”

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 61000-4-12, 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.

IEC 61000-4-28, Electromagnetic compatibility (EMC)—Part 4-28: Testing and Measurement Techniques—Variation of Power Frequency, Immunity Test.

IEC 61455, Nuclear Instrumentation—MCA Histogram Data Interchange Format for Nuclear Spectroscopy.

Manual for Railway Engineering, American Railway Engineering and Maintenance-of-Way Association, Mira Digital Publishing, Inc., 2003, Figure 28-1-3, page 28-1-5.<sup>9</sup>

MIL-STD-810F, Environmental Engineering Considerations and Laboratory Tests.<sup>10</sup>

NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum).<sup>11</sup>

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

<sup>10</sup> MIL publications are available from Customer Service, Defense Printing Service, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094.

<sup>11</sup> NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

### 3. Definitions

The following definitions apply to ANSI/IEEE standards that have been developed at the request of the U.S. Department of Homeland Security (DHS) for instruments to be used by DHS and emergency responders.

#### 3.1 General

**3.1.1 A-weighted sound level:** The frequency weighting of an acoustic spectrum according to a standardized frequency response-curve based on the frequency response of the human ear.

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

**3.1.3 accepted ambient photon background:** The background exposure rate as measured using a high pressure ionization chamber, an energy compensated Geiger-Mueller (G-M) tube, an energy compensated proportional counter, a tissue equivalent plastic scintillator, a scintillator with spectral compensation, or any other exposure rate meter having a nearly constant energy response ( $\pm 30\%$  in the energy range from 200 keV to 1.5 MeV).

**3.1.4 accredited testing laboratory:** Testing laboratory that has been accredited by an authoritative body with respect to its qualifications to perform verification tests on the type of instruments covered by this standard.

**3.1.5 accuracy:** The degree of agreement between the observed value and the conventionally true value of the quantity being measured.

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

**3.1.7 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.

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

**3.1.9 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.

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

**3.1.11 coefficient of variation (COV):** Ratio of the standard deviation,  $s$ , to the arithmetic mean,  $\bar{x}$ , of a set of  $n$  measurements,  $x_i$ , given by the following formula:

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

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

NOTE—This 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 (MQA) interaction with the National Institute of Standards and Technology (NIST) or an accredited calibration laboratory. (See ANSI N42.22 and ANSI N42.23.)<sup>12</sup>

**3.1.13 decade:** A range of values for which the upper value is a power of ten above the lower value.

**3.1.14 detection limits:** The extremes of detection or quantification for the radiation of interest.

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.

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

**3.1.16 effective center:** For a given set of irradiation conditions, the point within a detector where the response is equivalent to that which would be produced if the entire detector was located at the point.

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

**3.1.18 energy dependence:** Variation in instrument response as a function of radiation energy for a constant radiation type and exposure rate referenced to air.

**3.1.19 exposure:** 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.

**3.1.20 false alarm:** Alarm NOT caused by a radioactive source under the specified background conditions.

**3.1.21 functional check:** A frequently-used qualitative check to determine that an instrument is operational and capable of performing its intended function.

NOTE—Such checks may include, for example, battery check, zero setting, or source response check.

**3.1.22 indicated value:** (A) A scale or decade reading. (B) The displayed value of the readout. *See also: reading.*

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

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

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

NOTE—Also known as nuisance alarm.

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<sup>12</sup> Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

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

**3.1.27 instrument hour:** The number of operating instruments multiplied by the amount of time they are operating (i.e., 8 instruments operating for 3.75 h is equivalent to 30 instrument hours).

**3.1.28 interdiction:** Stopping the illicit or inadvertent movement of radioactive material that has been discovered as a result of radiation detection or measurement.

**3.1.29 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.

**3.1.30 overload response:** *See:* over-range response.

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

**3.1.32 performance test:** An evaluation of the performance of an instrument in response to a given influence quantity.

**3.1.33 point of measurement:** Place where the conventionally true values are determined and where the reference point of the instrument is placed for test purposes.

**3.1.34 precision:** Degree of agreement of repeated measurements of the same parameter.

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

**3.1.36 reading:** The indicated or displayed value of the readout.

**3.1.37 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.

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

**3.1.39 relative error ( $\epsilon_{REL}$ ):** The difference between instrument's reading,  $M$ , and the conventionally true value,  $CTV$ , of the quantity being measured divided by the conventionally true value multiplied by 100.

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

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

**3.1.41 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 level at the detector.

**3.1.42 restricted mode:** An advanced operating mode that can be accessed by an expert user (e.g., via password) to control the parameters that can affect the result of a measurement (e.g., radionuclide library, routine function control, calibration parameters, alarm thresholds).

NOTE—May also be called the “advanced” or “expert” mode.

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

**3.1.44 standard deviation:** The positive square root of the variance.

**3.1.45 standard instrument or source:** **(A)** National standard—a standard determined by a nationally-recognized competent authority to serve as the basis for assigning values to other standards of the quantity concerned. In the U.S., this is an instrument, source, or other system or device maintained and promulgated by the National Institute of Standards and Technology (NIST). **(B)** Primary standard—a standard that is designated or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quantity. **(C)** Secondary standard—a standard whose value is assigned by comparison with a primary standard of the same quantity. **(D)** Reference standard—a standard, generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived. **(E)** Working standard—a standard that is used routinely to calibrate or check material measures, measuring instruments, or reference materials. A working standard is traceable to NIST (see ANSI N42.22 and ANSI N42.23).

**3.1.46 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.

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

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

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

**3.1.50 upper measurement limit (UML):** The UML is the maximum level at which the instrument meets the required accuracy.

**3.1.51 variance ( $\sigma^2$ ):** 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.

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

## 3.2 Definitions of particular relevance to ANSI N42.43

**3.2.1 alarm assembly:** Equipment designed to indicate visually and/or audibly that the measured quantity exceeds a certain value.

**3.2.2 area monitor:** A monitoring system 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.

**3.2.3 detection zone:** A plane that is equivalent in width to the entire detection assembly and in height, as described in 5.1 (minimum height corresponds to the detection assembly dimension), placed at a distance from the detection assembly as listed in Table 2. Annex A shows a diagram of a detection zone.

**3.2.4 evaluation distances:** The distance between an evaluation test source and the exterior face(s) of the monitor unit(s), which corresponds to the surface of the detection assembly, during a trial (see 5.10.3).

**3.2.5 full width at half maximum (FWHM):** The full width of a distribution measured at half the maximum ordinate. For a normal distribution,  $FWHM = 2 \times (2 \ln 2)^{1/2} = 2.355$  times the standard deviation,  $\sigma$ .

**3.2.6 manufacturer:** Includes the designer of the equipment.

**3.2.7 mobile monitor:** Monitors that are typically in operation on a platform that is in motion.

NOTE—That platform could be a person as with a backpack-type monitor.

**3.2.8 monitored volume:** The volume between detectors for multiple detector systems, or the volume defined from ground level to a height given by the detector's upper end of the assembly, the width of the detection assembly, and the distance from the detection assembly given by the evaluation distance for single detector systems (see Table 2).

**3.2.9 occupancy time:** The period of time over which radiation emissions are measured.

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

**3.2.11 purchaser:** Includes the user of the equipment.

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

**3.2.13 reference point of the detection zone:** The reference point of the detection zone is that point that is at the center of the detection zone in both axes (horizontal and vertical) at a distance from the detection assembly based on the monitor type given by the evaluation distance (see Table 2).

**3.2.14 reference position of an assembly:** The vertical and horizontal center of a detection assembly or a physical mark on the detection assembly to be used for determining the performance of the equipment.

**3.2.15 standard test sources:** A set of check sources required to perform an evaluation and periodic operational testing.

**3.2.16 transportable monitor:** Monitors that are transported to a location and used for a specific task or for a specified period of time and that do not require permanent mounting platforms.

## 4. General considerations

Unless otherwise specified in individual steps, all tests enumerated in this standard are to be considered as type tests. If the manufacturer claims a broader range of operation (for example, an operating temperature range of  $-30\text{ }^{\circ}\text{C}$  to  $+55\text{ }^{\circ}\text{C}$ ), and the user requires this range, then additional testing and verification should be agreed upon between the manufacturer and customer. Certain tests may be considered as acceptance tests by agreement between the customer and manufacturer.

### 4.1 Evaluation of monitors

Testing is conducted under a set of conditions to determine if a monitor meets the requirements of this standard. Special applications, which could include a monitor's operation under weather conditions or detection needs that are not addressed by this standard, shall require additional testing.

Evaluation of monitors provides information to government agencies and other users on the capability of radiation-detection monitors for reliably detecting specified amounts of radioactive material.

## **4.2 Meeting performance specifications**

Obtaining operating performance that meets or exceeds the specifications as stated in this standard depends upon properly installing the monitor, establishing appropriate operating parameters, providing security for the systems, 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 uncertainties**

For the purposes of this standard, the radiological units of exposure rate (R/h) will be used for x-ray and gamma-ray radiation. Exposure rate may be converted to air-kerma rate to air by using the following conversion factor:  $1\text{R/h} = 876\text{ mrad/h}$  (8.76 mGy/h).

For x-rays and gamma-rays, the factor to convert from absorbed-dose-to-tissue (rad) to dose equivalent (rem) is equal to 1. Therefore, in conventional units  $1\text{ rad} = 1\text{ rem}$  and in SI units  $1\text{ Gy} = 1\text{ Sv}$ . Conversion coefficients can be used to convert from air-kerma to dose equivalent. The conversion coefficients are tabulated as a function of photon energy in the ISO/ FDIS 4037-3 standard.

For neutron radiation measurements, the radiological unit of dose equivalent (rem/h) will be used.

Throughout the text, radiological quantities will be expressed in conventional units; SI units are given in parentheses.

If uncertainties are not specified, they are set to  $\pm 5\%$ .

## **4.4 Special word usage**

The following word usage applies:

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

## **4.5 Standard test conditions**

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

**Table 1—Reference and standard test conditions**

Influence quantity	Standard test conditions (unless otherwise indicated by the manufacturer)
Stabilization time	≤15 min
Ambient temperature	18 °C to 25 °C
Relative humidity	10% to 75% RH
Atmospheric pressure	70 kPa to 106.6 kPa (525 to 800 mm of mercury at 0 °C)
Radiation Background	5 μR/h to 25 μR/h (0.05 μGy/h to 0.25 μGy/h)
Electromagnetic field of external origin	Less than the lowest value that causes interference
Magnetic induction of external origin	Less than twice the value of the induction due to earth's magnetic field
Instrument controls	Set up for normal operation
Contamination by radioactive elements	Negligible
Reference photon radiations	<sup>57</sup> Co, <sup>60</sup> Co, <sup>133</sup> Ba, <sup>137</sup> Cs, <sup>232</sup> Th, <sup>241</sup> Am.
Reference neutron radiation	<sup>252</sup> Cf

#### 4.6 Tests performed under standard test conditions

For these tests, the value of temperature, pressure, and relative humidity at the time of the test shall be recorded. Values should be within the standard test conditions.

#### 4.7 Tests performed with variation of influence quantities

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

#### 4.8 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuations of the indication arising from the random nature of radiation alone is a significant fraction of the variation of the indication permitted in the test, then the radiation exposure rate should be increased to ensure that the mean value of such readings may be estimated with sufficient accuracy to demonstrate compliance with the test in question. The coefficient of variation (COV) for each mean reading should be less than or equal to 12%.

The interval between such readings should be sufficient to ensure that the readings are statistically independent.

## 5. Design requirements

### 5.1 General characteristics

The monitors addressed by this standard shall detect changes in radiation levels emitted from objects, containers, vehicles, or pedestrians. These monitors may also have the ability to identify radionuclides. Identification requirements are listed in 6.14.

Monitors shall be capable of operating independently of any peripheral device or remote station, and they shall be unaffected by any malfunction of a peripheral device. Monitors should be self-powered in that there are supplies, such as generators or batteries, either on the vehicle or equipment to which the monitor is attached or integrated.

According to their use, monitors addressed by this standard are classified as:

- Area
- Containerized cargo
- Crane
- Pedestrian
- Rail
- Vehicle

NOTE—A monitor may be used in two or more classifications. However, its associated detection zone shall be appropriate for each classification.

Monitors should not be positioned farther apart than the distance at which they have proven to be effective. If the location of use requires distances or speeds other than those tested, testing to a limited source set shall be made prior to operation. The source set shall include  $^{57}\text{Co}$ ,  $^{137}\text{Cs}$ , and  $^{60}\text{Co}$ , and  $^{252}\text{Cf}$  as a minimum. For example, single-sided pedestrian monitors are evaluated at a distance of 1 m, but if they are evaluated and pass all requirements at a distance of 1.5 m, they may be used at this distance.

The “reference position” is located at the evaluation distance listed in Table 2 and is centered in both the height and width orientations of the entire detection assembly.

**Table 2—Evaluation distances for different applications**

Monitor use	Distance between detection assemblies	Evaluation distance
Transportable or mobile area monitors	N/A	Source 5 m from assembly
Single-sided, transportable, vehicle monitors (includes containerized cargo)	N/A	Source 5 m from assembly
Multiple-sided, transportable, vehicle monitors (includes containerized cargo and rail)	Detection assemblies 5 m apart	Source centered between detection assemblies
Mobile vehicle monitors	N/A	Source 3 m from face of detector or side of vehicle to which the detection assembly is mounted
Backpack	N/A	Source 3 m from the detector on either side of the backpack
Transportable pedestrian—single-sided	N/A	Source 1 m from detector
Transportable pedestrian—two-sided	Detection assemblies 1 m apart	Source centered between detection assemblies
Crane monitors	N/A	Along a line that runs parallel to the sensitive side of the detection assembly(s) at a distance of 3 m from the centerline of the face of the assembly(s). See 5.1.4 for more details.

### 5.1.1 Pedestrian

Transportable or mobile pedestrian monitors shall provide a detection zone to ensure that people are monitored. As a minimum, the height of the detection zone shall be from 0.1 m to 2 m above the ground. The distance between detection assemblies for evaluation purposes is listed in Table 2.

The passage or transit speed when a monitor is either in a fixed position or when the monitor is moving past fixed or stationary objects is listed in Table 3.

**Table 3—Speed of moving sources**

Monitor type	Source speed or monitor speed
Vehicle monitors—transportable	8 km/h (2.2 m/s)
Vehicle monitors—mobile	8 km/h (2.2 m/s)
Pedestrian monitors	1.2 m/s
Backpack monitors	1.2 m/s
Rail monitors	8 km/h (2.2 m/s)

## 5.1.2 Vehicle

### 5.1.2.1 Detection zones

Transportable vehicle monitors may be used for many different applications that may have different detection zones based on the height and size of the object being monitored. For example, when monitoring personal occupancy vehicles, the monitored detection zone may be from 0.5 m to 2.5m. For tractor trailers, the detection zone may be from 1 m to 4 m. In order to meet the requirements of both applications, the height of the detection assembly(s) may need to be adjustable.

### 5.1.2.2 Transportable systems

The manufacturer shall state the height of the detection zone over which the monitor meets the radiological requirements stated in this standard. The detection zone shall be at least 3 m in height over a range from 0.5 m to 4 m.

For testing purposes, the detection zone shall be from 0.5 m to 3.5 m unless otherwise directed by the manufacturer. The source-to-detector distance is listed in Table 2. The object passage speed should be at the speed listed in Table 3.

### 5.1.2.3 Mobile systems

The manufacturer shall state the height of the detection zone over which the monitor meets the radiological requirements stated in this standard. As a minimum, the detection zone shall be 2 m high.

For testing purposes, the height of the detection zone shall be from 1 m to 3 m above the ground or road surface with the detection assembly mounted at the same height as it is mounted when on the mobile platform. The source-to-detector distance is listed in Table 2. The passage speed (either object or monitor movement) should be the speed listed in Table 3.

## 5.1.3 Area, including backpack-type monitors

Area radiation monitors are designed to detect increases in radiation levels in a monitored area. The monitor shall be designed to continuously measure the ambient radiation levels and to alarm when the radiation level increases to a level that is above a set alarm point. Area monitors may be used to monitor people or items moving throughout the monitored area that is adjacent to the detection assembly(s), or as with a backpack-based monitor, as the monitor passes by or through an area. A monitor may consist of

multiple detection assemblies connected in such a way that each detector can operate alone or as a single detection assembly. For test purposes, the unit shall be tested with the source placed adjacent to each detector assembly at the distance stated in Table 2.

For backpack monitors, the source is moved past the backpack at the distance stated in Table 2 at the speed stated in Table 3. For test purposes, the centerline of the backpack should be positioned at a height of 1.5 m from the floor or ground surface.

Area monitors may be designed to be non-directional, providing 360° of coverage. If the monitor has this capability, the tests described in 6.4 and 6.5 shall be performed at 45° increments about the detection assembly.

#### **5.1.4 Crane**

Crane monitors, or any monitor that is attached to a mobile platform that holds the object being monitored, shall be able to detect radiation levels of interest emitted from the entire object. Monitors may use a single-detection assembly or multiple-detection assemblies.

As a minimum, the length of the detection zone relative to the center of the holding device shall be 8 m long ( $\pm 4$  m from the centerline of the holding device) with a height and width of 3 m. This detection zone (in the form of a rectangular box) will be located with the closest surface of the rectangular box at a distance of 0.2 m from the face of the detection assembly or assemblies.

Since the object to be monitored is in a fixed location for the measurement cycle, there is no passage speed requirement. For test purposes, the measurement time is 20 s.

Crane monitors shall not interfere with the functionality of the crane. For example, the monitor shall not restrict the extension or retraction of the spreader-bar mechanism on a container crane.

### **5.2 Physical configuration**

Enclosure(s) provided for outdoor assemblies, including those worn as backpacks, should be designed to meet the IP54 designation as designated in IEC 60529. If the monitor is mounted on a vehicle or other platform that can be transported, the enclosure shall meet the requirements of the IP55 designation (no damage by jetted water). Vent holes should be avoided if at all possible. External mounting hardware should be made from material that is resistant to corrosion (i.e., road salt).

The detection assemblies for road and rail vehicle monitoring or for use while in transit will be subjected to vibration and mechanical shock environments. Special precautions shall be taken to ensure safe transit and to reduce the transmission of shock and vibration to the monitoring system.

Mounting techniques used for detection assemblies attached to powered or towed vehicles shall be designed to ensure a degree of protection to the occupants of a vehicle from dislodged components of the monitor system in the event of a crash. Although this is not a performance requirement of the monitor, it is recommended that the mounted monitor and mounting components be designed to meet the requirements specified in MIL-STD-810F. For this requirement, the peak acceleration is 75 g at 8 ms to 13 ms.

Controls and adjustments that affect calibration and alarm settings shall be designed so that access to them is limited to authorized people.

Provisions shall be made to permit testing of visual or sound warning indicators without the use of radiation sources.

Provisions shall be made to permit testing of visual or sound warning indicators without the use of radiation sources. Displays shall be readable in low light levels ( $<150$  lux) and high light levels ( $>10000$  lux).

### 5.3 Data storage

The following list details monitor information for data storage:

- a) The monitor shall have the ability to internally store at least 1000 complete occupancy data sets if the monitor uses occupancy sensors. For monitors that do not use occupancy sensors, the monitor shall have the ability to store at least 3 h of continuous measurement data.
- b) Each occupancy data set shall contain collection results information including:
  - 1) Time and date in GMT format and local offset
  - 2) Occupancy time (if applicable)
  - 3) Monitor identification
  - 4) Monitor location (GPS for mobile systems)
  - 5) Monitor speed (when applicable)
  - 6) Alarm type (gamma-ray and/or neutron) and level (if applicable)
  - 7) Background (gamma and neutron) count rate
  - 8) Radionuclide identification results (when applicable)
  - 9) Radionuclide spectra (when applicable)
  - 10) Gamma-ray count rate (for individual detectors)
  - 11) Neutron count rate (for individual detectors if applicable)
- c) Monitors shall be able to store measurement data listed in item b), including background radiation levels and gamma-ray and neutron count rate time-history data locally, and shall have the ability to transfer user-selected portions of that data to a periphery device or location either through manual interface or remotely as required by the user and provided by the manufacturer.
- d) Monitors shall provide controlled access to real-time response data.
- e) Monitors shall have the ability to perform measurements with an object stationary in the detection zone or with the object moving through the detection zone either on its own, or with the object stationary and the monitor moving.

Fixed measurement times shall be user-selectable and the data shall be observable while being collected. If measurements were performed using fixed measurement times from the manufacturer, the times used shall be provided.

### 5.4 Indication features

The following list details information regarding indication features:

- a) The monitor shall provide an indication of its operational status and alarm condition, and shall be capable of transmitting these signals to a remote station. The user shall have the ability to select the visibility of the status indication.
- b) All alarm indicators shall be automatically or manually reset as defined by the user.
- c) Vehicle-based mobile systems shall have the ability to incorporate GPS for tracking purposes. For vehicle-based mobile systems, the operator shall be able to view the real-time GPS data on the user interface.

GPS tracking data shall be recorded at each data-logging interval whenever a GPS is used on any system addressed by this standard.

## 5.5 Occupancy and speed sensors for vehicle monitors

The following list details occupancy and speed sensors for vehicle monitors:

- a) Transportable monitors used primarily for vehicle monitoring applications shall have the ability to support occupancy sensors
- b) Transportable monitors used primarily for vehicle monitoring applications should have the ability to measure speed of the item as it passes through the detection zone or as the monitor passes the object
- c) If used, occupancy and speed sensors:
  - 1) Shall be able to detect presence and to estimate vehicle speed, indicate if a vehicle stops within the detection zone, and not count a single vehicle or object in the detection zone more than once
  - 2) Should be capable of operating on a mix of traffic (cars, vans, pickup trucks, buses, cargo trucks, trains, etc)
  - 3) Should function under all environmental conditions stated in this standard
- d) When systems are used to monitor rail vehicles, they should have the ability to approximate the location of an alarm when monitoring multi-car trains
- e) It shall be possible to trigger the occupancy sensor circuit using an external signal or through software for testing purposes

## 5.6 Markings

The following list details markings:

- a) Internal controls shall be identified through markings on electrical circuit boards and/or individual components and identification in technical manuals.
- b) Markings shall be easily readable and permanently fixed under normal conditions of use.
- c) Exterior markings shall be limited to the manufacturer's unique serial number, voltage, and current requirements if equipped with an outlet plug, and meet minimum code requirements.

## 5.7 Power supply

The following list details power supplies:

- a) Monitors shall have the ability to operate from multiple power sources.
- b) 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 .
- c) For DC, the monitor shall be able to operate from 12 V (11 V to 14.5 V).
- d) If operated using consumable batteries, the batteries shall be widely available, not unique to the instrument, and be field replaceable (e.g., AA, 9 V) with no special tools. Battery chargers shall meet U.S. electrical standards.
- e) Monitors designed for use on cranes shall be either self-powered (i.e., battery) or be capable of operation using power from the crane (i.e., 480 V AC).

## **5.8 Protection of switches**

Switches and other controls should be designed to ensure that the monitor can be operated properly while minimizing accidental switch operation.

## **5.9 Effective range of measurement**

The following list details effective ranges of measurement:

- a) The effective gamma-ray energy response range shall be stated by the manufacturer, and should be at least 50 keV to 3000 keV.
- b) The manufacturer shall state the range for gamma-ray count rate measurement and for neutron count rate indication.

## **5.10 Software and data analysis**

### **5.10.1 Communications protocol and data format**

The monitor 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 (i.e., 802.11), or RS-485. Consideration should be given to data security when using wireless data transfer techniques. When used, wireless techniques shall have the ability to be encrypted.

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

Data format shall be as defined in ANSI N42.42.

### **5.10.2 User interface**

#### **5.10.2.1 Warning/status indicators**

The following indications shall be provided at the user interface when applicable, as a minimum.

- Background changes that can affect the overall sensitivity of the monitor
- High-low detector count rate conditions (indication of background condition)
- Energy stabilization invalid or not acceptable
- Occupancy sensor failure, if occupancy sensors are used
- Changes in operational status (i.e., occupied, alarm, monitoring background, fault, blocked, etc)
- Low power
- Loss of line power
- Battery status
- Excessive speed (when applicable for vehicle portal monitoring)
- Overload indication
- Alarm indication
- Visual and audible, with alarm type (gamma or neutron) and level

### **5.10.2.2 Basic 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

### **5.10.2.3 Advanced indications and functions**

The following information and control shall be provided for the supervisory user through the use of access controls or special commands.

- Access to and control of operating parameters (alarm control)
- Access to and control of data logging intervals
- Access to alarm history
- Access to control of basic indication function
- Access to occupancy data set (if occupancy sensors are used)
- Access to vehicle photo (if available)
- Access to radiation profiles (count rate time history data)
- Access to background radiation information
- Access to alarm selection criteria

### **5.10.3 Radiation response indication**

The following information and control shall be provided at the user display:

- Strip-chart display of gamma and neutron counts
- Spectral display from gamma detectors, if applicable
- Real-time access to data stored as listed in item b) of 5.3
- Real-time mapping with GPS data and alarm locations (for mobile systems).

## **5.11 Operating parameters**

The manufacturer shall provide the list of recommended operating parameters (e.g., alarm thresholds, detector voltage, gain). These parameters shall be used throughout testing.

## **6. Radiological tests**

### **6.1 General**

#### **6.1.1 Background radiation during testing**

The evaluation shall be performed in an area with a nominal natural background environment that has only natural variation.

The gamma-ray background intensity shall be measured using a pressurized ion chamber or similar environmental radiation measurement device that is calibrated with respect to NIST standards to provide gamma-ray exposure rate. If the monitor is equipped with neutron detectors, the neutron background should be the natural background and should not be artificially modified during testing.

#### **6.1.2 Monitor set-up**

Monitors shall be set up based on the manufacturer's specifications. Once set-up for testing, no changes shall be made that could affect the overall response of the monitor.

For backpack-type systems, when performing radiation response testing, the backpack shall be configured as it would be used. This may be achieved by using a person or a phantom that would represent the upper torso.

### **6.2 Speed of moving sources or mobile system**

During testing, the source or monitor shall be moved in a configuration that provides no shielding around the source other than that required for the specific test. The movement speed shall be at the speed specified in Table 3 for the specific type of monitor.

### **6.3 Evaluation distances**

The detector response is determined by transporting the test sources through the detection zone at the specified speed given in Table 3. The set-up or evaluation distances for different applications are given in Table 2; these distances are measured from the detector case or assembly.

The count time used for test purposes shall be specified by the manufacturer and should be not more than 1 min.

### **6.4 Fixed object tests**

For monitors designed to measure radiation levels with an object in a fixed position in the detection zone, the monitor shall be set-up according to manufacturer's specifications, and the source shall be quickly moved into the detection zone reference position in a way that mimics to the extent practical the actual field measurement. For example, the detection assembly shall be moved or the source moved at a speed of 1 m per second, then held in one of the test positions, then moved away from the source at the same speed. The count time used for test purposes shall be specified by the manufacturer and should be not more than 1 min.

## 6.5 Detector response

The evaluation shall be performed without the benefit of any radiation shielding against the natural background, except for that shielding that is a permanent feature of the monitor.

**Table 4—Activity values for gamma-ray and neutron sources**

Radionuclide	Activity (μCi) unshielded <sup>(4)</sup>	Activity (μCi) steel-shielded (3 cm) <sup>(4)</sup>	Activity (μCi) poly-shielded (7.62 cm radius) <sup>(4) (5)</sup>
<sup>133</sup> Ba	9	148	--
<sup>57</sup> Co	15	--	--
<sup>60</sup> Co	7	25	--
<sup>137</sup> Cs	16	85	--
DU <sup>(6) (7)</sup>	4.5 kg (46 cm <sup>2</sup> )	--	--
<sup>67</sup> Ga	16	--	94
HEU <sup>(6) (7)</sup>	237 g (6.5 cm <sup>2</sup> )	--	--
<sup>131</sup> I	10	--	23
<sup>192</sup> Ir	6	61	--
<sup>40</sup> K	128	--	--
<sup>237</sup> Np <sup>(6) (7)</sup>	90 mg with 1 cm Fe shielding	--	--
<sup>99m</sup> Tc	16	--	127
<sup>201</sup> Tl	10	--	88
<sup>226</sup> Ra	8	--	--
<sup>232</sup> Th	14	--	--
RGPu <sup>(6) (7)</sup>	1.4 g with 1 cm Fe shielding	--	--
WGPu <sup>(6)</sup>	15 g with 1 cm Fe shielding	--	--
<sup>252</sup> Cf <sup>(3)</sup>	$2 \times 10^4$ n/s $\pm$ 20%	--	--

<sup>(1)</sup> Values stated are based on calculations performed using published information available at the time of drafting, and are based on photon emission rates using those photons with energies greater than 25 keV with the radioactive material contained in a 0.25 mm stainless steel encapsulation. An emission rate of 500 000 gamma-rays/s was used as a basis. This was determined using the approximate emission rate of <sup>137</sup>Cs for an exposure rate of 5 μR/h (0.05 μGy/h) at 1 m.

<sup>(2)</sup> The actual activity of each source at the time of testing shall be not more than 20% greater than the value shown in Table 4. The uncertainty in the actual activity value shall be less than 10% (1σ). All sources activities shall be traceable to NIST.

<sup>(3)</sup> The neutron source is encapsulated in 1 cm steel and 0.5 cm lead.

<sup>(4)</sup> Unless otherwise stated, the shown mass values are based on a total gamma-ray leakage of 500,000 gamma-rays/s at energies greater than 40 keV.

<sup>(5)</sup> “Poly” = polymethyl methacrylate.

<sup>(6)</sup> The amounts of HEU and DU are stated in terms of cross-sectional area as well as the mass of solid spheres. This is because these sources are surface emitters and the cross-sectional area determines the flux. WGPu, RGPu, and <sup>237</sup>Np are shielded with 1 cm Fe for handling purposes due to ES&H issues and for particularly Pu, they emit quite a few low-energy gamma rays that don’t contribute to the ability to identify the isotopes. 20 years as an age is used as a basis for the transport calculations.

<sup>(7)</sup> For this standard, HEU has an enrichment that is at least 93.5% <sup>235</sup>U, DU at 0.2% <sup>235</sup>U, and U<sub>nat</sub> at 0.7%. RGPu contains 24% <sup>240</sup>Pu and WGPu 6% <sup>240</sup>Pu.

## 6.6 Reference gamma radiation

Unless otherwise stated, tests involving the use of gamma radiation shall be carried out using the reference radionuclide,  $^{137}\text{Cs}$ .

The gamma radiation levels stated in Table 4 are for testing only. They are not indicative of the alarm set point or overall sensitivity of the monitoring system that is established based on the ambient background and acceptable false alarm rate.

## 6.7 False alarm test

### 6.7.1 Requirements

NOTE—False alarms may be caused by inadequate counting statistics, background intensity variations, and/or equipment malfunction. Gross-count rate capabilities are generally adjusted using alarm thresholds that interrelate overall sensitivity and false alarm rates.

When tested in an area with a stable background (only natural fluctuations) at the levels stated in Table 1, the false alarm rate shall be less than 1 per 1000 occupancies or 1 alarm over a period of time that is equivalent to the time required to completely monitor 1000 objects for monitors that do not use occupancy sensors.

The manufacturer shall provide an estimate of the background level at which the monitor will no longer meet these requirements, and state the minimum time required between occupancies to differentiate multiple vehicles or objects.

### 6.7.2 Test method

Perform a minimum of 1000 occupancies, or observe the monitor over a period of time that is equivalent to the time required to completely monitor 1000 objects. The test shall be performed in an area that has a stable and controlled background. The results are acceptable if no more than one alarm occurs.

For example, if the time required to monitor a truck/trailer with a vehicle monitor is 5 s and the monitor does not use occupancy sensors, for 1000 occupancies the test time is 5000 s or 83.3 min.

For monitors without occupancy sensors, the time required for 1000 monitoring cycles shall be recorded.

NOTE—Mobile monitors are tested while stationary.

## 6.8 Detector response to gamma radiation

### 6.8.1 Requirements

An alarm shall be triggered when the measured count rate is greater than the alarm setting. This requirement shall be verified using  $^{241}\text{Am}$ ,  $^{232}\text{Th}$ ,  $^{137}\text{Cs}$ ,  $^{133}\text{Ba}$ ,  $^{60}\text{Co}$ , and  $^{57}\text{Co}$ . Source activities for this test are given in Table 4.

The instrument response is acceptable when a minimum of 59 alarms occur in 60 occupancies or passes.

## 6.8.2 Test method

For transient monitoring systems, using  $^{241}\text{Am}$ ,  $^{232}\text{Th}$ ,  $^{133}\text{Ba}$ ,  $^{60}\text{Co}$  and  $^{57}\text{Co}$ , pass each source horizontally (see Table 2) through the detection zone at the required test speed (see Table 3) through the bottom, middle, and top of the detection zone, and the mid-point between the middle and bottom, and middle and top planes. Record the number of alarms in 60 occupancies.

For stationary measurements, manually start a measurement cycle with each source positioned in the horizontal center of the detection zone at the application-specific distance (see Table 2). The heights shall be based on the application and are the bottom, middle, and top of the detection zone, and the mid-point between the middle and bottom and middle and top planes. Record the number of alarms in 60 trials.

Area monitors that are designed to be non-directional providing 360° of coverage shall be tested with the source placed in the reference position 6 m from the centerline of the detection assembly. The exposure shall be repeated at 45° increments about the detection assembly. There shall be 10 exposures per angle increment.

Backpack monitors are tested using the non-directional format stated above with the source moving at the reference speed (see Table 3) at the reference distance (see Table 2). The entire monitor and stand (see 6.1.2) shall be rotated in 45° increments with the exposure process repeated at each increment. The centerline of the source shall be the same as the centerline of the monitor, 1.5 m.

For crane monitors, or any monitor that is designed to detect radiation with the object fixed in the detection zone, the test shall be performed with the source in the center of the detection zone at each required elevation, then along a line that runs parallel to the detection assembly (the orientation where monitoring takes place) that is 8 m long. The test distance shall be at each end of the monitoring length.

## 6.9 Detector response to neutron radiation

### 6.9.1 Requirements

An alarm shall be triggered when the monitor is exposed to a  $^{252}\text{Cf}$  neutron emission rate of 20,000 n/s (see Table 4) for a duration specified by the manufacturer or at the passage speed as appropriate for the monitor type being tested.

The instrument response is acceptable when a minimum of 59 alarms occur in 60 occupancies or passes.

### 6.9.2 Test method—unmoderated

Using the neutron source from Table 4, verify that the monitor alarms when passing the source through the detection zone at the required transit speed (see Table 3) at the application-specific distance from the detection assembly(s) (see Table 2). The transit heights shall be based on the application and are the bottom, middle, and top of the detection zone, and the mid-point between the middle and bottom, and middle and top planes. Record the number of alarms in 60 occupancies.

Area monitors that are designed to be non-directional providing 360° of coverage shall be tested with the source placed in the reference position 6 m from the centerline of the detection assembly. The exposure shall be repeated at 45° increments about the detection assembly. There shall be ten exposures per angle increment.

Backpack monitors are tested using the non-directional format stated above with the source moving at the reference speed (see Table 3) at the reference distance (see Table 2). The entire monitor and stand (see 6.1.2) shall be rotated in 45° increments with the exposure process repeated at each increment. The centerline of the source shall be the same as the centerline of the monitor, 1.5 m.

For crane monitors, or any monitor that is designed to detect radiation in a fixed position with the object fixed in the detection zone, the test shall be performed with the source in the center of the detection zone at each required elevation, then along a line that runs parallel to the detection assembly (the orientation where monitoring takes place) that is 8 m long. The test distance shall be at each end of the monitoring length.

### **6.9.3 Test method—moderated**

Repeat the test stated in 6.9.2 with the neutron source placed in a moderator that is equivalent to 122 cm of pine.

## **6.10 Overload test**

### **6.10.1 Requirements**

If a monitor is exposed to a radiation field that is greater than the manufacturer-stated maximum during an occupancy, or when performing measurements without an occupancy sensor, an alarm indicating, for example, “high background” 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 monitor is not fully operational.

The time required to return to non-alarm condition after the exposure rate is returned to background levels shall not be greater than 1 min.

### **6.10.2 Test method**

Initiate a monitoring cycle with the monitor operating in a stable background. Simultaneously, using  $^{137}\text{Cs}$  increase the ambient background by a minimum of 10 mR/h (100  $\mu\text{Gy/h}$ ) as measured at the surface of the detection assembly while the monitor is occupied. The monitor shall alarm and remain in alarm until the radiation field is reduced to the pre-test level. Within 1 min of the removal of the source, the monitor shall return to the pre-test count rate.

The system shall alarm and recover successfully in three successive tests.

## **6.11 Neutron indication in the presence of photons**

### **6.11.1 Requirements**

Gamma radiation at exposure rates of up to 10 mR/h (100  $\mu\text{Gy/h}$ ) (at the face of the center of the detection assembly) shall not trigger the neutron alarm. In addition, the monitor shall be able to detect an increase in neutron radiation while being exposed to gamma radiation.

### **6.11.2 Test method**

Using  $^{137}\text{Cs}$ , increase the ambient gamma exposure rate by 10 mR/h (100  $\mu\text{Gy/h}$ ) as measured at the center of the surface of the detection assembly while the monitor is occupied or otherwise monitoring for changes in radiation levels. Remove the radiation source and allow the monitor to return to normal operation, and repeat the test for a total of three trials.

Immunity of neutron detectors to gamma radiation is confirmed if no neutron alarms are triggered.

Repeat the gamma exposure, but this time expose the monitor to the unmoderated neutron source and verify that the neutron alarm activates.

## **6.12 Background effects—monitor is stationary during use**

### **6.12.1 Requirement**

The monitor shall provide a warning indication when a change in background is large enough to cause a substantial change in alarm probability. The indication shall be visual and/or audible (the type of alarm shall be user selectable) and shall be different than monitoring alarms.

### **6.12.2 Test method**

Without triggering an occupancy (if occupancy sensors are used) move the  $^{137}\text{Cs}$  and  $^{252}\text{Cf}$  sources (listed in Table 4) starting from at least 10 m away from the center of the detection zone at a speed of 0.08 km/h towards and eventually through the detection zone, or until a point where the monitor indicates that the background has changed substantially. This test shall be performed three times. The monitor shall indicate that the background has changed for each trial.

## **6.13 Background effects—monitor is mobile during use**

### **6.13.1 Requirement**

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. The indication shall be visual and/or audible (the type of alarm shall be user selectable) and shall be different than monitoring alarms.

### **6.13.2 Test method**

The test should be done by allowing the monitor to update background while positioned in an area where the background is a factor of five greater than the normal background in that area. The increase may be done using  $^{226}\text{Ra}$  or  $^{137}\text{Cs}$ . Once the monitor is operational in the increased background area, the background level will be cycled between the higher value and the lower value while initiating a counting cycle during the low-level background exposure. The test will be performed in two ways, with an additional radiation source and without the additional source to test for false and missed alarms, respectively.

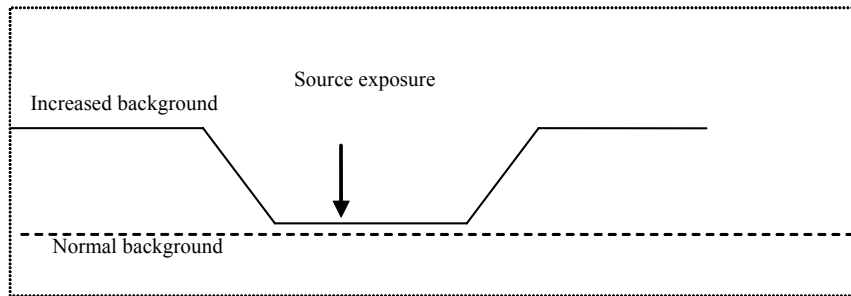
To perform the test, measure the ambient background using a suitable instrument, such as an ion chamber, and document the reading. Increase the ambient background as measured at the detection assembly using a radiation source to a level that is a factor of five greater than the normal background. Note the position of the source for later use.

Allow the monitor to update background in the increased background area (see Figure 1). Without initiating a measurement cycle (if applicable), move the monitor or the source at a speed of 50 cm/s from the artificial background to an area of normal background. After a period of 10 s, initiate a count cycle and begin increasing the background to the high level. Once back to the artificial (high) background area, stop the count cycle, if applicable, and note whether the unit alarmed. Repeat the process nine additional times for a total of ten trials. To be acceptable, no alarms shall occur in ten out of ten trials. Repeat the entire process but this time, after the 10 s delay expose the monitor to a  $^{137}\text{Cs}$  source that produces an additional

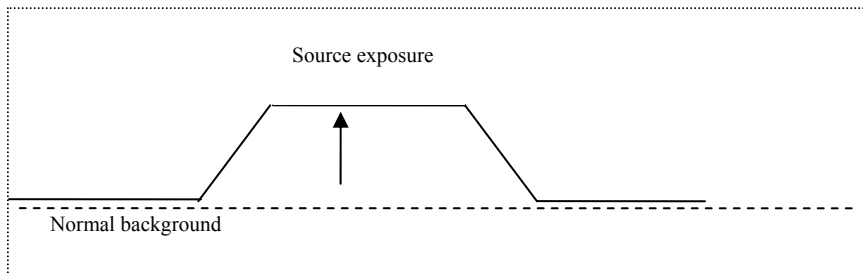
50  $\mu\text{R/h}$  (0.5  $\mu\text{Gy/h}$ ) at the detector during the counting cycle. The monitor shall alarm in ten out of ten trials.

Allow the monitor to update background in the normal background area (see Figure 2). Without initiating a measurement cycle (if applicable), move the monitor or source at a speed of 50 cm/s from normal background to the artificial background area. After a period of 10 s, initiate a count cycle and begin decreasing the background to the normal level. Once back to the normal background area, stop the count cycle, if applicable, and note whether the unit alarmed. Repeat the process nine additional times for a total of ten trials. To be acceptable, no alarms shall occur in ten out of ten trials. Repeat the entire process but this time, after the 10 s delay expose the monitor to a  $^{137}\text{Cs}$  source that produces an additional 50  $\mu\text{R/h}$  (0.5  $\mu\text{Gy/h}$ ) at the detector assembly face during the counting cycle. The monitor shall alarm in ten out of ten trials.

Each complete cycle should take approximately 30 s.



**Figure 1—Increased background exposure**



**Figure 2—Normal background exposure**

## 6.14 Radionuclide identification—when provided

When testing the identification capabilities of spectroscopy-based radiation monitors, the monitor shall identify the radionuclide(s) of interest, or that radionuclide(s) and expected daughter(s), and no others. If naturally-occurring radionuclides such as  $^{40}\text{K}$  are identified during a controlled test, actions should be taken to reduce or eliminate the source of radiation prior to continuing the test.

NOTE 1—Manufacturers may use  $^{40}\text{K}$  to ensure that their system is functioning properly. This response is typically addressed by background subtraction when a measurement is performed.

### 6.14.1 Radionuclide categorization

NOTE—The IAEA Code of Conduct on the Safety and Security of Radioactive Sources contains a list of radionuclides and categories. *This is an informative list and should not be considered as all-inclusive.*

- Special nuclear materials: Uranium (used to indicate  $^{233}\text{U}$ ,  $^{235}\text{U}$ ),  $^{237}\text{Np}$ , Pu
- Medical radionuclides:  $^{18}\text{F}$ ,  $^{67}\text{Ga}$ ,  $^{51}\text{Cr}$ ,  $^{75}\text{Se}$ ,  $^{89}\text{Sr}$ ,  $^{99}\text{Mo}$ ,  $^{99\text{m}}\text{Tc}$ ,  $^{103}\text{Pd}$ ,  $^{111}\text{In}$ , Iodine ( $^{123}\text{I}$ ,  $^{131}\text{I}$ ),  $^{153}\text{Sm}$ ,  $^{201}\text{Tl}$ ,  $^{133}\text{Xe}$
- Naturally-occurring radioactive materials (NORM):  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and daughters,  $^{238}\text{U}$  and daughters
- Industrial radionuclides:  $^{57}\text{Co}$ ,  $^{60}\text{Co}$ ,  $^{133}\text{Ba}$ ,  $^{137}\text{Cs}$ ,  $^{192}\text{Ir}$ ,  $^{204}\text{Tl}$ ,  $^{226}\text{Ra}$ , and  $^{241}\text{Am}$

#### 6.14.1.1 Requirement

The manufacturer shall state the radionuclides that the monitor can identify and their categories. The categories selected should be based on the list shown in 6.14.1. The list shall contain as a minimum, the radionuclides listed in Table 4.

#### 6.14.1.2 Test method

Verify that the requirement is met by review of manufacturer's provided information.

### 6.14.2 Single radionuclide identification

#### 6.14.2.1 Requirement

The manufacturer shall provide a list of radionuclides that the monitor can identify.

If the manufacturer claims the ability to detect Highly Enriched Uranium (HEU), Reactor Grade Plutonium (RGPu), or Weapons Grade Plutonium (WGPu), perform 6.14.2.3. If no claims are made, 6.14.2.3 is not required.

#### 6.14.2.2 Test method—unshielded

Using the applicable technique (refer to the clauses describing how to perform gamma alarm testing), transient or fixed measurement, attempt to have the monitor identify each of the sources listed in Table 4, except for  $^{252}\text{Cf}$ .

For transitory measurements, pass each source through the detection zone horizontally at the required test speed (see Table 3) at the application-specific distance (see Table 2). The transit heights shall be based on the application and are the bottom, middle, and top of the detection zone.

The test shall consist of ten consecutive trials for each radionuclide in each configuration as required for that monitor's application. The monitor's alarm shall be reset between each trial, if appropriate. The performance is acceptable when the monitor correctly identifies the radionuclide in ten out of ten consecutive trials.

NOTE—It is not necessary to validate the identification of non-listed radionuclides.

### **6.14.2.3 Test method—unshielded SNM**

Repeat the test described in 6.14.2.2 using HEU, RGPu, and/or WGPu.

### **6.14.3 Identification of shielded radionuclides**

#### **6.14.3.1 Requirements based on shielding related to shipping containers**

The manufacturer shall provide a list of shielded radionuclides that the monitor can identify. For this standard, the source is surrounded by 3 cm of steel on all sides.

The list shall contain the following radionuclides, as a minimum:

$^{133}\text{Ba}$ ,  $^{137}\text{Cs}$ , and  $^{60}\text{Co}$

NOTE—3 cm steel is based on possible shipping container configurations and attenuation of gamma-ray emissions from each radionuclide.

#### **6.14.3.2 Requirements based on medical treatments**

The manufacturer shall provide a list of radionuclides that the monitor can identify when monitoring people with medical treatments. For this standard, the source is surrounded by 7.62 cm of polymethyl methacrylate (PMMA). The list shall contain the following radionuclides, as a minimum:

$^{67}\text{Ga}$ ,  $^{99\text{m}}\text{Tc}$ ,  $^{131}\text{I}$ , and  $^{201}\text{Tl}$

#### **6.14.3.3 Test method**

Tests shall be performed to verify claims made based on the lists shown in 6.14.3.1 and 6.14.3.2.

For transitory measurements, pass each source horizontally through the detection zone at the required test speed at the application-specific distance (see Table 2). The transit heights shall be based on the application and are the bottom, middle, and top of the detection zone. Source activities are shown in Table 4.

For stationary measurements, manually start a measurement cycle (see 6.4) with each source positioned in the horizontal center of the detection zone at the application-specific distance (see Table 2). The heights shall be based on the application and are the bottom, middle, and top of the detection zone. As in the transitory measurements, source activities are shown in Table 4.

The test shall consist of ten consecutive trials for each radionuclide in each configuration as required for that monitor's application. The monitor shall be reset between each trial, if appropriate. The performance is acceptable when the monitor correctly identifies the radionuclide in ten out of ten consecutive trials.

## 6.14.4 Simultaneous radionuclide identification

### 6.14.4.1 Requirement

The monitor shall have the ability to identify more than one radionuclide simultaneously. Simultaneous identification ability shall consist of radionuclides from separate categories (e.g.,  $^{99m}\text{Tc}$  +  $^{137}\text{Cs}$ ,  $^{131}\text{I}$  + RGPu).

The monitor shall have the ability to identify a radionuclide of interest when combined with other radionuclides.

### 6.14.4.2 Test method

Testing shall be performed using the following combinations of radionuclides from 6.14.2.1. The activities shall be based on the activities shown in Table 4.

$^{40}\text{K}$  +  $^{226}\text{Ra}$  +  $^{232}\text{Th}$  + RGPu  
 $^{40}\text{K}$  +  $^{226}\text{Ra}$  +  $^{232}\text{Th}$  + DU  
 $^{99m}\text{Tc}$  + DU  
 $^{131}\text{I}$  + RGPu

For transitory measurements, pass each source combination horizontally through the detection zone at the required test speed and at the application-specific distance (see Table 2). The transit heights shall be based on the application and are the bottom, middle, and top of the detection zone. The test shall be performed using the radionuclides listed in Table 4 in the unshielded configuration.

For stationary measurements, manually start a measurement cycle (see 6.4) with each source combination positioned in the horizontal center of the detection zone at the application-specific distance (see Table 2). The heights shall be based on the application and are the bottom, middle, and top of the detection zone. As in the transitory measurements, the test shall be performed using the radionuclides listed in Table 4 in the unshielded configuration.

The test shall consist of ten consecutive trials for each radionuclide combination. The monitor shall be reset between each trial, if appropriate. The performance is acceptable when the monitor correctly identifies the radionuclides in ten out of ten consecutive trials.

## 6.14.5 Overload characteristics for identification

### 6.14.5.1 Requirement

The manufacturer shall state the maximum gamma-ray exposure rate ( $\mu\text{R/h}$ ) relative to  $^{137}\text{Cs}$  for identification.

### 6.14.5.2 Test method

Increase the ambient exposure rate using  $^{137}\text{Cs}$  to the maximum exposure rate for radionuclide identification as stated by the manufacturer (or at least by 0.1 mR/h (1  $\mu\text{Gy/h}$ ) at the face of the detection assembly if there is no manufacturer stated value available) and perform a radionuclide identification using  $^{60}\text{Co}$  at the activity level indicated in Table 4. The monitor shall correctly identify  $^{60}\text{Co}$ . This test is acceptable if the monitor correctly identifies  $^{60}\text{Co}$  in ten out of ten consecutive trials.

## 6.14.6 Pile-up effects

### 6.14.6.1 Requirement

The monitor shall correctly identify radiation activities associated with people who have recently received radiation therapy treatments ( $^{131}\text{I}$ ).

### 6.14.6.2 Test method

Testing shall be performed using a 30 mCi  $^{131}\text{I}$  source placed in a PMMA shield (see 6.14.3.2)

For transitory measurements, pass the source horizontally through the detection zone at the required test speed (see Table 3) and at the application-specific distance (see Table 2)). The transit height is the middle of the detection zone.

For stationary measurements, manually start a measurement cycle (see 6.4) with the source positioned in the horizontal center of the detection zone at the application-specific distance (see Table 2). The test height is the middle of the detection zone.

The test shall consist of ten consecutive trials. The monitor shall be reset between each trial, if appropriate. The performance is acceptable when the monitor correctly identifies the radionuclide in ten out of ten consecutive trials.

## 6.15 Determination of full-energy-peak efficiency

### 6.15.1 Requirement

The manufacturer shall state the full-energy-peak efficiency for  $^{57}\text{Co}$  (122 keV at 85.51 %,  $T_{1/2} = 272$  days),  $^{133}\text{Ba}$  (356 keV at 62.05 %,  $T_{1/2} = 10.5$  years),  $^{137}\text{Cs}$  (662 keV at 85.1 %,  $T_{1/2} = 30$  years), and  $^{60}\text{Co}$  (1173 and 1332 keV at 99.857 % and 99.983 % respectively,  $T_{1/2} = 5.27$  years).

NOTE—Data from Evaluated Nuclear Structure Data File (ENSDF, National Nuclear Data Center (NNDC)) and Bureau National de Métrologie-Laboratoire National Henri Becquerel/Commissariat à l'énergie atomique (BNM-LNHB/CEA).

### 6.15.2 Test method

Prior to performing the test, collect a 1 min background spectrum, and record the total counts obtained. One at a time, position each source at the center of the detection zone in the reference position, and collect a spectrum until a minimum of 10 000 net counts are obtained. Determine the full-energy-peak efficiency for each source by:

$$\eta_a = 100 \frac{A}{N_s}$$

where:

$\eta_a$  absolute counting efficiency (%)

$A$  counts in the full-energy peak, less background

$N_s$  total number of photons of the given energy emitted by the source during the counting time

Record the efficiency, the system-stated full-energy-peak value, and its associated channel number on the test data sheet. If the system uses multiple detectors, perform the test for each detector.

## **6.16 Determination of full width-half maximum (FWHM) (spectroscopic monitors only)**

### **6.16.1 Requirement**

The manufacturer shall state the FWHM as defined in the IEEE standard appropriate to the detector used for  $^{137}\text{Cs}$  (662 keV at 85.1%).

### **6.16.2 Test method**

NOTE—Information gained from the performance of 6.15 may be used to determine the FWHM.

Place each source at a position that is 1 m from the surface of each detection assembly centered over a detector.

NOTE—This position may not be the center of the detection assembly.

Collect a minimum of 10 000 counts, and determine the FWHM. Record the results in percent on the data sheet for each detector. The determined FWHM shall be within  $\pm 20\%$  of the manufacturer-stated FWHM.

## **7. Environmental performance requirements**

NOTE 1—Electrical, electromagnetic, mechanical, and environmental tests shall be performed with  $^{137}\text{Cs}$  and  $^{252}\text{Cf}$  (if the monitor is equipped with neutron detectors) sources listed in Table 4 unless otherwise stated.

NOTE 2—It is permissible, but not recommended, to test the system by testing components only, such as detector(s) and controller. Portions of the system that are not intended for uncontrolled environments or that will not affect the radiological response of the system, such as the trailer or powered vehicle, may be excluded from this test. If cooling or heating systems are part of the detection system, it is not possible to test components only.

### **7.1 Ambient temperature**

#### **7.1.1 Requirement**

The monitor shall be able to operate over an ambient temperature range from  $-30^{\circ}\text{C}$  to  $+55^{\circ}\text{C}$ .

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

#### **7.1.2 Test method—non-spectroscopic monitors**

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  $10^{\circ}\text{C}$  per hour.

For this test, the monitor's response consists of collecting a series of gross gamma and neutron readings using  $^{137}\text{Cs}$  and  $^{252}\text{Cf}$ . The response is determined from ten readings. Record the count rate induced by

ambient background and by the radioactive sources. Calculate the mean, the standard deviation, and the coefficient of variation for the ten readings.

The results are acceptable if the mean reading obtained at each temperature test point is within  $\pm 15\%$  of the mean reading obtained at the nominal temperature.

Prior to the test, expose the monitor to a radiation field to obtain the monitor's response at the nominal temperature and relative humidity (RH) of 22 °C and <65% RH, respectively. The coefficient of variation (COV) for each mean reading shall 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. The mean reading shall then be used to establish the acceptance range of  $\pm 15\%$ .

Following the nominal temperature stabilization period of 2 h, decrease the temperature at a rate not exceeding 10 °C/hour to the low temperature test point (−30 °C). The monitor shall be observed during the temperature ramp and any functional changes recorded. The temperature shall be maintained at the low temperature test point for a minimum of 16 h. The monitor's response shall be obtained at the beginning, middle, and end of the 16 h period and results compared with the pre-test response.

Following the low temperature soak, increase the temperature at the 10 °C/hour rate stopping at −20, 0, and +40 °C for a period of 4 h at each test point. The monitor shall be observed during the temperature ramp and any functional changes recorded. The monitor's response shall be obtained during the last 30 min of each test temperature. Increase the temperature to the upper temperature test point (55°C) at a rate not exceeding 10 °C/hour and maintain the temperature for a minimum of 16 h. The monitor's response shall be obtained at the beginning, middle, and end of the 16 h period and results compared with the pre-test response.

Following the upper temperature exposure, return the temperature to the nominal temperature and after a 2 h stabilization period, obtain the monitor's response and compare the post-test results with the pre-test results to complete the test.

If available, trigger the occupancy sensor at each temperature to verify it operates at all tested values.

### **7.1.3 Test method—spectroscopic monitors**

For this test, the monitor's response shall consist of collecting a series of gross gamma-ray and neutron readings using <sup>57</sup>Co and <sup>60</sup>Co, and <sup>252</sup>Cf (see Table 4 for source information). The response shall also consist of a ten trial identification using <sup>57</sup>Co and <sup>60</sup>Co. Record the identification results as x number of correct identifications out of ten trials for each radionuclide.

The results at each temperature test point from each series of identifications shall be the same or better than the identification results obtained at the nominal temperature to be acceptable. For example, if the ten-trial results at 22 °C and <65% RH are correct in six out of ten trials, the results at each test point shall be six or more correct. For the gross response channels, the results are acceptable if the mean readings obtained at each temperature test point are within  $\pm 15\%$  of the mean readings obtained at the nominal temperature.

Prior to the test, obtain the monitor's response at the nominal temperature and relative humidity (RH) of 22 °C and <65% RH, respectively. The coefficient of variation (COV) for each mean reading shall be less than or equal to 12%. If the COV is greater than 12%, the exposure rate should be increased to reduce the variation between each reading. The mean readings shall then be used to establish each acceptance range of  $\pm 15\%$ . In addition, while at the nominal temperature, perform a ten-trial radionuclide identification using <sup>57</sup>Co and <sup>60</sup>Co and record the results as x number of correct for ten trials for each radionuclide.

Following the nominal temperature stabilization period of 2 h, decrease the temperature at a rate not exceeding 10 °C/hour to the low temperature test point. The monitor shall be observed during the temperature ramp and any functional changes recorded. The temperature shall be maintained at the low

temperature test point for a minimum of 16 h. The monitor's response shall be obtained at the beginning, middle, and end of the 16 h period.

Following the low temperature exposure at  $-30^{\circ}\text{C}$ , increase the temperature at the  $10^{\circ}\text{C}/\text{hour}$  rate stopping at  $-20^{\circ}\text{C}$ ,  $0^{\circ}\text{C}$ , and  $+40^{\circ}\text{C}$  for a period of 4 h at each test point. The monitor shall be observed during the temperature ramp and any functional changes recorded. The monitor's response shall be obtained during the last 30 min of each test temperature. Increase the temperature to the upper temperature test point of  $55^{\circ}\text{C}$  at a rate not exceeding  $10^{\circ}\text{C}/\text{hour}$  and maintain the temperature for a minimum of 16 h. The monitor's response shall be obtained at the beginning, middle, and end of the 16 h period.

Following the upper temperature exposure, return the temperature to the nominal temperature and after a 2 h stabilization period, and obtain the monitor's response.

## 7.2 Relative humidity

### 7.2.1 Requirement

The monitor shall be able to operate during and after exposure to relative humidity (RH) levels of up to 93% RH at an ambient temperature of  $+40^{\circ}\text{C}$ .

There shall not be any observable effects from the exposure.

### 7.2.2 Test method

NOTE—It is permissible, but not recommended to test the system by testing components only, such as detector(s) and controller. Portions of the system that are not intended for uncontrolled environments may be excluded from this test. If cooling or heating systems are part of the detection system it is not possible to test components only.

For this test, the monitor's response consists of collecting a series of gross gamma and neutron readings using  $^{137}\text{Cs}$  and  $^{252}\text{Cf}$ . The response is determined from ten readings. Record the count rate induced by ambient background, and by the radioactive sources. Calculate the mean, the standard deviation and the coefficient of variation for the ten readings.

The results are acceptable if the mean reading obtained at each temperature test point is within  $\pm 15\%$  of the mean reading obtained at the nominal temperature.

Prior to the test, the monitor's response shall be obtained at the nominal temperature and relative humidity (RH) of  $22^{\circ}\text{C}$  and 40% RH respectively. The coefficient of variation (COV) for each mean reading shall 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 each reading. The mean reading shall then be used to establish the acceptance range of  $\pm 15\%$ .

Following the nominal conditions stabilization period of 2 h, increase the humidity and temperature at a rate not exceeding 10% RH and  $10^{\circ}\text{C}$  per hour respectively until attaining  $93 \pm 3\%$  RH and  $40^{\circ}\text{C}$ . The humidity shall be maintained at this value for 16 h and the monitor's gamma-ray and neutron readings noted every hour and results compared with the pre-test response.

The humidity shall then be reduced to 65% RH at a rate not exceeding 10% RH per hour while maintaining the temperature at  $40^{\circ}\text{C}$ . Obtain the monitor's response after allowing the monitor to stabilize in those conditions for a minimum of 2 h and compare the results with the pre-test response. Reduce the temperature to  $22^{\circ}\text{C}$  at rate of  $10^{\circ}\text{C}$  per hour to complete the test. Record the monitor's response and compare it with the pre-test response.

Following the test, each exposed assembly shall be inspected for corrosion or other affects caused by humidity.

If available, trigger the occupancy sensor at each testing point to verify it operates at all tested values.

### **7.3 Moisture and dust protection**

#### **7.3.1 Requirement**

The monitor including components designed for use in an unprotected environment shall meet the requirements stated for IP code 54 (see IEC 60529). The instrument shall be 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, and water splashed against the enclosure from any direction shall have no harmful effects.

If the monitor is mounted to the exterior of a vehicle or other platform that can be transported, the enclosure shall meet the requirements of the IP55 designation (no damage by jetted water). Vent holes should be avoided if at all possible. Monitors designed for use at port facilities will be exposed to salt mist. Mounting hardware or other similar components that could be exposed to the salt mist environment shall be designed to reduce or prevent corrosion.

This requirement is not for monitors or components mounted to the inside of a vehicle other than those designed for maritime operations.

#### **7.3.2 Test method—dust**

The test shall be conducted in a dust chamber (see IEC 60529, category 2) where the powder circulation pump may be replaced by other means suitable to maintain the talcum powder (or Portland cement) in suspension in a closed test chamber. The amount of powder to be used should be 2 kg per cubic meter of the test chamber volume. The powder shall not have been used for more than 20 tests.

If the monitor uses multiple detector assemblies, it is only necessary to test one assembly.

The monitor shall be exposed to a  $^{137}\text{Cs}$  source that is of sufficient intensity to minimize the effect of the statistical fluctuations of the radiation readings ( $\text{COV} \leq 12\%$ ). The monitor shall then be exposed to the dust environment for a period of 1 h. The monitor shall respond to the presence of radiation throughout the test and after the test. The results are acceptable if the mean reading obtained at each temperature test point is within  $\pm 15\%$  of the mean reading obtained at the nominal temperature.

Following exposure, an inspection shall be performed 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.

If available, trigger the occupancy sensor while inside the dust chamber to verify it operates at all tested environments.

#### **7.3.3 Test method—moisture**

The test shall be made using a suitable nozzle (see IEC 60529, spray nozzle) with the water pressure adjusted to give flow rate of  $10 \text{ L/min} \pm 5\%$ , which should be kept constant during the test. The water temperature should not differ by more than 5 K from the temperature of the monitor under test. The test duration is  $1 \text{ min/m}^2$  of the calculated surface area of the monitor with a minimum duration of 15 min.

Prior to the test, the monitor shall be exposed to a  $^{137}\text{Cs}$  source that is of sufficient intensity to minimize the effect of the statistical fluctuations of the radiation readings ( $\text{COV} \leq 12\%$ ). The monitor shall then be exposed to the water spray. The spray nozzle should be located approximately 2 m from the monitor. The monitor shall respond to the presence of radiation throughout the test and after the test. The results are acceptable if the mean reading obtained at each temperature test point is within  $\pm 15\%$  of the mean reading obtained at the nominal temperature.

The nozzle shall be positioned such that it is directly pointed at a vertical side of the monitor. During the exposure, the orientation shall be changed by  $+60^\circ$  and  $-60^\circ$  in two orthogonal planes along each side of the monitor. The monitor shall be tested in its field use orientation. All sides shall be exposed.

Following exposure, the monitor shall be inspected to ensure that moisture did not penetrate.

If available, trigger the occupancy sensor at each testing point to verify it operates at all tested values.

## **8. Electrical and electromagnetic performance requirements**

### **8.1 Radio frequency (RF)**

#### **8.1.1 Requirement**

The monitor should not be affected by RF fields over the frequency range of 80 MHz to 2500 MHz at an intensity of 10 V/m. Because backpacks are typically used where they may be exposed to the higher intensities found in close proximity to cell phones, the performance requirement for RF is 50 V/m.

#### **8.1.2 Test method**

Place the complete monitor or those components that have the greatest potential for susceptibility in a controlled RF environment and expose it to a RF field of 20 V/m (50 V/m for backpacks) over a frequency range of 80 MHz to 2500 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 greater 1% of the fundamental (previous) frequency. Dwell time should be chosen based on the monitor's response time, but should not be less than 3 s.

NOTE—20 V/m is selected so that the test can be performed in one orientation. Backpacks will require to be tested in multiple orientations.

If susceptibilities are indicated by substantial changes in the indicated readings (deviations exceeding  $\pm 15\%$  of the initial mean gamma-ray or neutron readings) or other operational changes such as alarm activation, the RF exposure shall be repeated over the range of susceptibility at 10 V/m (50 V/m for backpacks) in three orientations relative to the emission source.

The test is acceptable if no alarms, spurious indications, or changes in response occur that exceed  $\pm 15\%$  of the initial indicated value.

### **8.2 Radiated emissions**

#### **8.2.1 Requirement**

The emission limits when measured at 3 m shall be less than what is shown in Table 5:

**Table 5—Emission frequency range**

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

### 8.2.2 Test method

NOTE—A non-shielded room is acceptable provided the ambient RF environment is well known and controlled.

Place the monitor in an area with a low and controllable radio frequency environment. Position an antenna three meters from the assembly. With the monitor off, collect a background spectrum using a scanning bandwidth of 50 kHz. Switch the monitor on and perform an RF scan for both non-occupancy and occupancy operations. The monitor shall be positioned to ensure that the measurement is performed where the emissions are at the highest intensity.

Radio frequency emissions shall be below the values stated in Table 5.

## 8.3 AC line voltage operation

### 8.3.1 Requirement

For those monitors capable of operating from 120/240 V power, the requirement is: AC lines with a supply voltage that is within  $\pm 12\%$  of the nominal voltage and within  $\pm 3\%$  frequency.

### 8.3.2 Test method

Place the  $^{137}\text{Cs}$  and  $^{252}\text{Cf}$  test sources in a location that provides a stable response. With the supply voltage at its nominal value determine the mean gamma and neutron readings, the standard deviation and the coefficient of variation from series of ten readings.

Increase the supply voltage to 12% above the nominal value. Determine and record each channel's mean reading. Decrease the supply voltage to 12% below the nominal value and again determine and record the mean readings.

The above tests shall be repeated but instead of changing the voltage, the frequency shall be changed from 58 Hz to 62 Hz.

The results are acceptable if the mean readings obtained at each voltage or frequency test point are within  $\pm 15\%$  of the mean reading obtained at the nominal voltage and frequency.

## 8.4 Battery life-time

### 8.4.1 Requirement

Monitors other than those designed for use on cranes 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**

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

Disconnect the AC line, as appropriate, and using only  $^{137}\text{Cs}$ , perform an occupancy at 10 s intervals with the source passing through the mid-point of the detection zone. Perform the test for 8 h.

To be acceptable, the 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**

The instrument shall not be affected by exposure to electrostatic discharges at intensities of up to 6 kV using the contact discharge technique.

### **8.5.2 Test method**

In order to evaluate a monitor's immunity to ESD, the contact discharge technique shall be used. Discharge points shall be selected based on user accessibility.

There shall be ten discharges per discharge point with a 1 s recovery time between each discharge. It is recommended that tests first be performed at 2 kV, then if acceptable, 4 kV, followed by 6 kV.

The test is acceptable if no alarms or other spurious indications occur, and there is no substantial change in response (reproducible deviations not exceeding  $\pm 15\%$  of the initial mean gamma-ray or neutron readings).

This test shall be performed under non-occupancy and occupancy operations.

## **8.6 Conducted disturbances induced by bursts and radio frequencies**

### **8.6.1 Requirement**

The monitor shall not be affected by RF fields that can be conducted onto the monitor through an external conducting cable.

### **8.6.2 Test method**

Place the  $^{137}\text{Cs}$  gamma-ray and the  $^{252}\text{Cf}$  neutron test sources in a location that provide stable readings and expose the monitor to a conducted RF field over the frequency range of 150 kHz to 80 MHz at an intensity of 140 dB ( $\mu\text{V}$ ) 80% amplitude modulated with a 1 kHz sine wave.

The test should be performed using an automated sweep at a frequency change rate not greater 1% of the fundamental (previous) frequency. Dwell time should be chosen based on the monitor's response time, but should not be less than 3 s.

The test is acceptable if no alarms or other spurious indications occur, and there is no substantial change in response (deviations not exceeding  $\pm 15\%$  of the initial mean gamma-ray or neutron readings).

This test shall be performed under non-occupancy and occupancy operations.

## **8.7 Surges and oscillatory waves**

### **8.7.1 Requirement**

The monitor should not be affected by surges or oscillatory waves of up to 2 kV that are classified as ring waves or combination waves at 1.2/50  $\mu$ s and 8/20  $\mu$ s.

### **8.7.2 Test method**

Apply ten pulses to the device with a minimum time between surges of 1 min. Each pulse should consist of a combination wave (1.2/50  $\mu$ s and 8/20  $\mu$ s) at an intensity of 2 kV.

Apply ring wave pulses of not more than 2 kV.

The test is acceptable if no alarms or other spurious indications occur, and there is no substantial change in response (deviations not exceeding  $\pm 15\%$  of the initial mean gamma-ray or neutron readings).

This test shall be performed under non-occupancy and occupancy operations.

## **9. Mechanical performance requirements**

### **9.1 Microphonics/impact**

#### **9.1.1 Requirement**

The monitor shall be unaffected by microphonic conditions such as those that may occur from low intensity sharp contacts at energies of up to 1.0 J. 1.0 J is equivalent to a mass of 1 kg moving at 1.4 m/s over a distance of 0.1 m.

#### **9.1.2 Test method**

Using an appropriate test device (i.e., spring hammer), expose the detector assembly to three 1.0 J impacts. The test shall be performed on each side of the detection assembly while observing the response.

The test is acceptable if no alarms or other spurious indications occur, and there is no substantial change in response (deviations not exceeding  $\pm 15\%$  of the initial mean gamma-ray or neutron responses).

The test shall be repeated for non-occupancy and occupancy operations.

### **9.2 Vibration**

#### **9.2.1 Requirement—fixed operations**

The radiation monitoring system shall function normally after exposure to conditions associated with truck transportation over U.S. highways for two-wheeled trailers and wheeled vehicles. The limits are discussed in MIL-STD-810F, Category 4. See Table 6.

**Table 6—Break points for curves of figures**

Vertical		Transverse		Longitudinal	
Hz	g <sup>2</sup> /Hz	Hz	G <sup>2</sup> /Hz	Hz	g <sup>2</sup> /Hz
10	0.01500	10	0.00013	10	0.00650
40	0.01500	20	0.00065	20	0.00650
500	0.00015	30	0.00065	120	0.00020
		78	0.00002	121	0.00300
		79	0.00019	200	0.00300
		120	0.00019	240	0.00150
		500	0.00001	340	0.00003
				500	0.00015
1.04	g rms	0.204	G rms	0.740	g rms

NOTE—See MIL-STD-810F, Table 514.5C-VII.

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).

### 9.2.2 Requirement—mobile operations, including backpacks

The monitor should function normally during exposure to the vibration environments described in 9.2.1.

### 9.2.3 Test method

Prior to the test, a series of readings using <sup>137</sup>Cs and <sup>252</sup>Cf (gamma and neutron, respectively) shall be obtained. The coefficient of variation (COV) for each mean reading shall 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 each reading. The mean readings shall then be used to establish each acceptance range of ±15%.

Depending on use, either remove the sources or leave the sources present and subject the detection assembly and any other component that may be operated in the same environment to the applicable harmonic loadings over the applicable frequency range.

The test shall consist of three 60 min exposures, one for each orientation or direction. For fixed operations, the monitor should be switched off during exposure with measurements taken after each orientation. For mobile systems, the monitor shall be operational during exposure.

The test is acceptable if no alarms or other spurious indications occur, and the mean readings determined from a series of readings from each channel following vibration is within ±15% of the pre-test gamma-ray and neutron mean readings.

After the test, inspect the monitor for mechanical damage and loose components. Note the results of the inspection on the data sheet.

## 9.3 Mechanical shock

### 9.3.1 Fixed operations requirement

The radiation monitoring system shall function normally after exposure to 30 g mechanical shocks in the vertical direction. 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).

### **9.3.2 Requirement—mobile operations, not including backpacks**

The monitor should function normally during exposure to 30 g mechanical shocks in the vertical direction. 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).

### **9.3.3 Requirement—mobile operations, backpacks**

The monitor should function normally during exposure to ten shock pulses of 50 g peak acceleration, each applied for a nominal 18 ms in each of three mutually orthogonal axes. The physical condition of instruments shall not be affected by these shocks (e.g., solder joints shall hold; nuts and bolts shall not come loose).

### **9.3.4 Requirement—crane-mounted systems**

Monitors shall be designed to function normally when exposed to shock levels of 200 g.

### **9.3.5 Test method**

Prior to the test, a series of readings using  $^{137}\text{Cs}$  and  $^{252}\text{Cf}$  (gamma and neutron, respectively) shall be obtained. The coefficient of variation (COV) for each mean reading shall 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 each reading. The mean readings shall then be used to establish each acceptance range of  $\pm 15\%$ .

Depending on use, remove the sources and subject the detection assembly and any other component that may be operated in the same environment to mechanical shocks.

The test shall consist of ten shock exposures in each of three orthogonal orientations.

The test is acceptable if no alarms or other spurious indications occur, and the mean readings determined from a series of readings from each channel during and following exposure in each orientation is within  $\pm 15\%$  of the pre-test gamma-ray and neutron mean readings.

After the test, inspect the monitor for mechanical damage and loose components. Note the results of the inspection on the data sheet.

## **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 Certification**

The manufacturer shall provide a certificate and evaluation report containing at least this information:

- Contact information for the manufacturer including name, address, telephone #, fax #, email address, etc
- Type of instrument, detector and types of radiation the instrument is designed to measure
- Evaluated portal width and mounting parameter

- Sensitivity switch settings, detector bias level (lower level discriminator setting), and all significant calibration parameters such as  $^{137}\text{Cs}$  662 keV gamma-ray pulse height in scintillation detectors or neutron pulse height in  $^3\text{He}$  proportional counters
- Power supply requirements
- Results of tests under environmental conditions
- Results of electrical and mechanical tests
- Recommended operational parameters such as: detector response and false alarm probability
- Complete description of the evaluated monitor

### **10.3 Operation and maintenance manual**

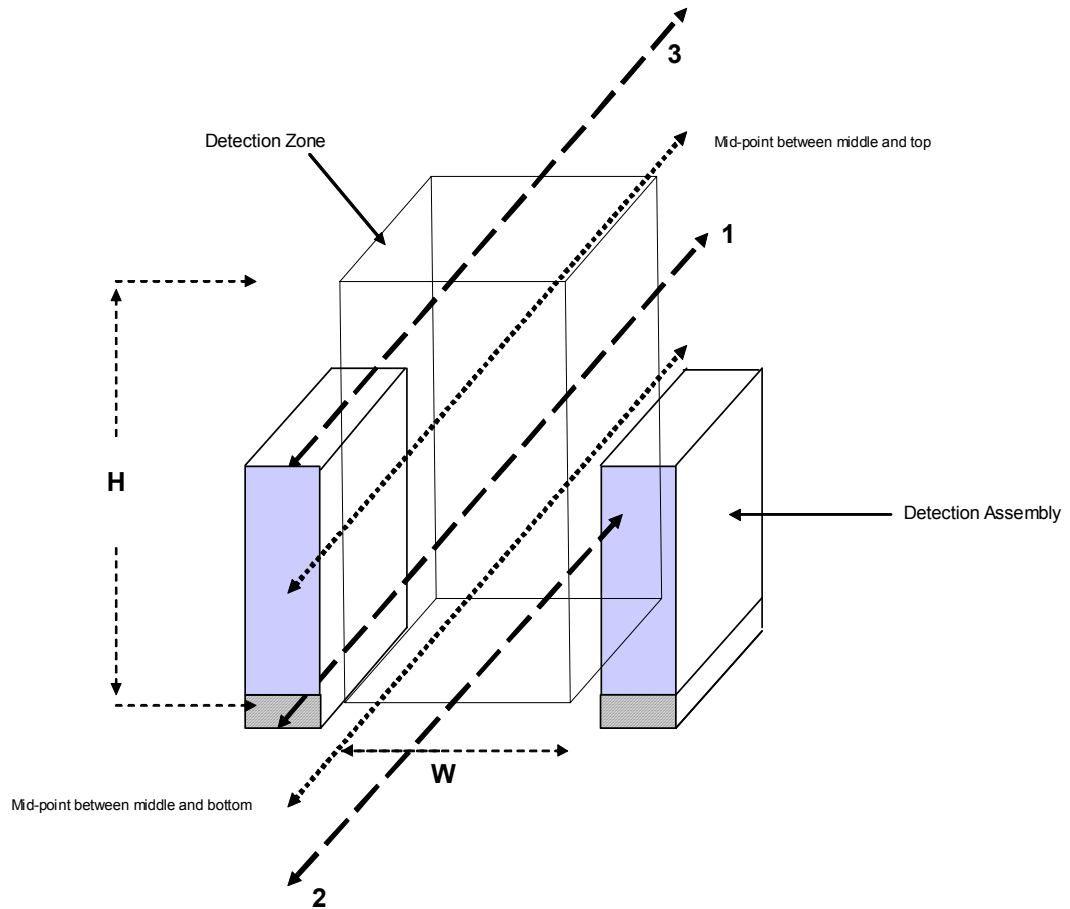
The manufacturer shall supply an operational and maintenance manual containing the following information to the user:

- Operating instructions and restrictions
- Schematic electrical diagrams plus spare parts list and specifications
- Troubleshooting guide
- A detailed training manual or instructions for operators and users
- Description and protocol for communication methods of transmitting and receiving data

## Annex A

(informative)

### Diagram of mounting dimensions for radionuclide identifying portal monitors



$W$  = Width of the detection zone

$H$  = Height of the detection zone

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

Positions are indicated as follows:

2 = bottom

1 = center (reference) of detection zone

3 = top