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# American National Standard Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides

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Sponsored by the
National Committee on Radiation Instrumentation, N42



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**American National Standards Institute**

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

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**Abstract:** The performance requirements for hand-held radionuclide identifying instruments are described in this standard. The requirements stated are based on instruments used in support of efforts associated with the U.S. Department of Homeland Security.
**Keywords:** radionuclide identifiers, restrictive mode, routine mode

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## Contents

# American National Standard Performance Criteria for Hand-Held Instruments for the Detection and Identification of Radionuclides

## 1. Overview

### 1.1 Scope

This standard specifies general requirements and test procedures, radiation response requirements, and electrical, mechanical, and environmental requirements. Successful completion of the tests described in this standard should not be construed as an ability to identify all radionuclides in all environments.

### 1.2 Purpose

This standard addresses instruments that can be used for homeland security applications to detect and identify radionuclides, for gamma-ray exposure rate measurement, and for indication of neutron radiation.

## 2. Normative references

This standard shall be used in conjunction with the following publications. 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.[1]

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

[1] The ANSI N42 publications included in this clause are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

ANSI N42.42, American National Standard Data Format Standard for Radiation Detectors Used for Homeland Security.[2]

FCC Rules, Code of Federal Regulations, Title 47, Part 15, Radio Frequency Devices.[3]

IAEA Safety Guide No. RS-G-1.9, Categorization of Radioactive Sources.[4]

IEC 60068-1, Environmental Testing—Part 1: General Guidance.[5]

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), IP53.

IEC 61000-4-1, Electromagnetic Compatibility (EMC), Part 4-1: Testing and Measurement Techniques—Overview of IEC 61000-4 Series.

IEC 61000-4-2, Electromagnetic Compatibility (EMC)—Part 4-2: Testing and Measurement Techniques—Electrostatic Discharge Immunity Test.

IEC 61000-4-3, Electromagnetic Compatibility (EMC)—Part 4-3: Testing and Measurement Techniques—Radiated, Radio-Frequency, Electromagnetic Field Immunity Test.

IEC 61000-4-6, Electromagnetic Compatibility (EMC)—Part 4-6: Testing and Measurement Techniques—Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields.

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

ISO/IEC 4037-3, X and Gamma Reference Radiation for Calibrating Dosemeters and Doserate Meters and for Determining the Response as a Function of Photon Energy—Part 3: Calibration of Area and Personal Dosemeters and Measurement of Their Response as a Function of Energy and Angle of Incidence.[6]

## 3. Definitions

The following definitions apply to this standard, as well as to ANSI N42.32 [B11][7], ANSI N42.33 [B12], and ANSI N42.35 [B13], all of which 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.

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**3.1 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.

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[2] The ANSI N42.42 schema can be obtained from http://physics.nist.gov/Divisions/Div846/Gp4/ANSIN4242/xml.html.

[3] 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/).

[4] 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).

[5] 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 (www.ansi.org)..

[6] ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/ Suisse (http://www.iso.ch/). ISO 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/).

[7] The numbers in brackets correspond to those of the bibliography in Annex A.

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

**3.3 accepted ambient photon background:** The background radiation as measured using a high pressure ionization chamber, an energy compensated Geiger-Mueller (GM) tube, an energy compensated proportional counter, a tissue equivalent plastic scintillator, a scintillator with spectral compensation, or any other exposure rate instrument having a nearly constant energy response (±30% in the energy range from 60 keV to 1.5 MeV).

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

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

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

**3.7 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.

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

**3.9 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.

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

**3.11 coefficient of variation (COV) (%):** The square root of the variance, $\sigma^2$, divided by the mean value of "n" number of readings times 100.

**3.12 confidence indication:** An indication provided by the instrument of the reliability assigned to the determined identification.

NOTE—This definition is of particular relevance to ANSI N42.34.[8]

**3.13 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.)

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

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

**3.15 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.

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

**3.17 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.

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

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

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

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

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

**3.22 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.

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

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

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

**3.26 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 called a nuisance alarm.

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

**3.28 instrument hour:** That period of time that the instrument is powered on and operating.

NOTE—The number of operating instruments multiplied by the amount of time they are operating (e.g., eight instruments operating for 3.75 h is equivalent to 30 instrument hours).

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

**3.30 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.

**3.31 over-range response:** The response of an instrument when exposed to radiation intensities greater than the upper detection limit.

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

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

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

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

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

**3.37 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.

**3.38 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.

**3.39 relative error [$\varepsilon_{REL}$ (%)]:** 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.

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

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

**3.41 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 field at the detector.

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

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

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

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

**3.45 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).

**3.46 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.

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

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

**3.49 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.

**3.50 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.

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

## 4. General considerations

Unless otherwise specified in the 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 °C to +55 °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 Standard test conditions

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

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

### 4.2 Units and uncertainties

For the purposes of this standard, the radiological units of exposure rate (R/h) shall be used for x-ray and gamma radiation. Exposure rate can be converted to air-kerma rate by using the following conversion factor: 1R/h = 876 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 rad = 1 rem and in SI units 1 Gy = 1 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 ISO/IEC 4037-3.

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

If uncertainties are not specified for a measurable quantity, they are set to ±5%.

### 4.3 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.

**Table 1—Standard test conditons**

| Influence quantity | Standard test conditions |
|---|---|
| Stabilization time | As stated by the manufacturer. |
| Ambient temperature | 18 °C to 25 °C |
| Relative humidity | 20% to 75% |
| Atmospheric pressure | 70 kPa to 106.6 kPa (525 mm to 800 mm of mercury at 0 °C) |
| Battery voltage | Fresh batteries |
| Angle of incidence of radiation | Direction given ±5° |
| Electromagnetic field of external origin | Negligible |
| Magnetic induction of external origin | Negligible |
| Instrument controls | Set up for normal operation. |
| Radiation background | Ambient photon exposure rate of 5 μR/h to 25 μR/h |
| Contamination by radioactive elements | Negligible |

## 5. General characteristics

### 5.1 General

Instruments addressed by this standard are used for the detection and identification of radionuclides, for gamma-ray exposure rate measurement, and for indication of neutron radiation. They typically acquire the gamma-ray spectrum and identify the radionuclide through comparison with an internal radionuclide library.

These instruments are hand-held and battery-powered. They shall be operable for a minimum of 2 h of continuous use and shall be capable of operating at temperatures from –20 °C (–4 °F) to +50 °C (+122 °F). Instruments used outside of this or other stated requirements should be tested to ensure proper operation prior to use.

Other than a radiation detector, an instrument shall not require any external devices (i.e., laptop personal computer) for the detection and identification of radioactive material.

## 5.2 Test preparation

NOTE— Step 5.2.1 through step 5.2.7 shall be used when preparing to do a test based on this standard.

### 5.2.1 Manufacturer, model, and serial number

Record the manufacturer's name along with the model, serial number, and firmware number of the instrument and detector, if separate.

### 5.2.2 Documentation supplied

Verify that instructions for operating and checking the operation of the instrument have been supplied and record the result of this verification. Check for all items listed in Clause 10.

### 5.2.3 Type of radiation detector

Identify and record the type of instrument (gamma only or gamma/neutron) and the radiation detector types used (e.g., NaI, CZT, HPGe, $^{3}$He). Verify the type of alarm from the manufacturer's documentation (audible, visible, vibratory) and record.

### 5.2.4 Size

Note the dimensions specified by the manufacturer. Measure the dimensions (thickness, width, and length) of the instrument and record.

### 5.2.5 Weight

Note the weight specified by the manufacturer.

### 5.2.6 Case construction

Examine the case to verify that it is smooth, rigid, has no uncovered openings to the interior space, and has the reference point for the detector marked. Record the results of the examination.

### 5.2.7 Photograph

Photograph the instrument and retain the photo in the record.

## 5.3 Operating modes

### 5.3.1 Requirement

The instrument shall have at least two different operating modes as follows:

— *Routine mode:* An operating mode that includes detection and identification of radionuclides and exposure rate measurement. Also may be called the "simple mode."

— *Restricted mode:* An advanced operating mode that can be accessed by an expert user (i.e., 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). Also may be called the "advanced" or "expert" mode.

#### 5.3.2 Test method

The manual shall be reviewed and direct observation of the instrument display made to verify the requirement. The results of the verification shall be recorded.

### 5.4 Markings

#### 5.4.1 General requirements

All external instrument controls, displays, and adjustments shall be identified as to function. Internal controls needed for operation shall be identified through markings and identification in technical manuals. External markings shall be easily readable and permanently fixed under normal conditions of use (including use of normal decontamination procedures).

The following markings shall appear on the exterior of the instrument or each major subassembly (i.e., detector probe) as appropriate:

a) Manufacturer and model number

b) Unique serial number

c) Location of the effective center(s) or area(s) of detection (reference point)

d) Function designation for controls, switches, and adjustments that are not menu or software driven

#### 5.4.2 Test method

The instrument shall be inspected and the results of the inspection shall be recorded.

### 5.5 Communication interface

#### 5.5.1 Requirement

The instrument shall have the ability to transfer data to an external device, such as a computer. The transfer should be based on a bi-directional port that meets the requirements of Ethernet, USB, wireless, or other electronic means such as a removable media device. Consideration should be given to data security when using wireless data transfer techniques. The technique used shall conform to applicable IEEE protocols. Communication protocols shall be described in the technical manual and proprietary formats shall not be used.

Proprietary software should not be required for remote data interpretation. The transferred data shall be in the XML format. The manufacturer shall provide proprietary software for data interpretation, if needed.

The data format defined in ANSI N42.42 shall be used.

#### 5.5.2 Test method

The data transfer requirements are verified in step 5.6 and step 5.10.

## 5.6 User interface

### 5.6.1 Requirement

The instrument shall include:

a) A display that is easily readable over the required temperature range and under different lighting conditions

b) Controls that are user-friendly for routine operation

c) Controls and switches that are designed in a way to minimize accidental operation

d) A menu structure that is simple and easy to be followed intuitively

e) At least two different operating modes (see 5.3)

f) The capability to operate if the user is wearing gloves

g) A user-definable radionuclide library with access via the restricted mode

### 5.6.2 Test method

In order to test the above requirements, a minimum of *three potential users* of this type of instrument shall review the operating instructions provided by the manufacturer. Following the review, each potential user shall operate the instrument in the routine operation mode. Specifically, the potential user shall:

a) Turn on the instrument and verify that it is working properly (e.g., the battery is charged, the detector is present and working, memory is available, self-check passed)

b) Calibrate (if necessary)

c) Make an exposure rate measurement

d) Make an identification (of a single radionuclide) and save the data

e) Transfer the data to an external device, such as a computer

f) Using the manufacturer provided password for access (if applicable), ensure that the radionuclide library can be accessed (do not make any changes)

g) Turn off the instrument

Step a) through step d) shall be done in low light levels (<150 lux) and repeated in high light levels (>10 000 lux). A separate test following step a) through step d) shall also be performed with the potential user wearing protective gloves. Gloves worn shall be typical of those used for thermal protection.

A survey form (see Annex C) shall be completed by each potential user to assess the usability of the instrument's controls, interface, and operation. A report shall be generated based on the survey results.

## 5.7 Warm-up time

### 5.7.1 Requirement

The manufacturer shall state the time required for the instrument to become fully functional from either a dead start or when in a standby mode. The maximum time shall be less than 2 min.

### 5.7.2 Test method

The test shall be performed using the following technique.

Switch the instrument on and after the manufacturer-stated warm-up time or 2 min, whichever is shorter, perform a simultaneous identification using $^{241}$Am and $^{60}$Co. Verify that the instrument is able to perform the identification within the manufacturer-stated identification time or 2 min whichever is the shorter, and provide an indication of the gamma-ray exposure rate. If the instrument has neutron response capabilities, expose the instrument to an unmoderated neutron source ($^{252}$Cf) and document whether it responds to the source.

## 5.8 Battery power

### 5.8.1 Requirements

The following requirements shall be verified through the performance of the same ordered test methods listed in 5.8.2:

a) Instruments shall be equipped with a test circuit or other visible direct indicator of battery condition for each battery circuit.

b) The manufacturer shall state the expected continuous operating time using the recommended batteries and the conditions (functional and environmental) used to determine this time.

c) The instrument shall be fully operational for a minimum of two continuous hours after warm-up under standard test conditions. The low-battery indication shall be no lower than the minimum voltage required for proper operation.

d) If operated using consumable batteries, the batteries shall be widely available, shall not be unique to the instrument, and shall be field replaceable (e.g., AA, 9 V) with no special tools. Battery chargers shall meet U.S. electrical standards.

e) The instrument should be capable of operating from an external DC source. Adequate protection from reverse polarity, over-voltage, and electrical noise must be provided. DC power sources include:

   1) Nominal 12 VDC, as would be obtained from a 12 V vehicle electrical system

   2) A portable battery pack, such as one that can be worn, that supplies 9 VDC to 14 VDC

   3) A regulated 12 VDC power supply operating from utility power

### 5.8.2 Test method

The test shall be performed using the following technique:

a) Verify through review of the manual and direct observation of the instrument display and record the results.

b) Verify manufacturer-stated battery lifetime through review of the manual, and record the results.

c) To verify the requirement stated in item c) in 5.8.1, ensure that the batteries are fully charged and after allowing the instrument to warm up, perform a simultaneous radionuclide identification using $^{241}$Am and $^{60}$Co. The instrument shall also be tested using an unmoderated neutron source (neutron indication test). Leave the instrument on and after a period of 2 h, perform another radionuclide identification and neutron indication test. The instrument shall be able to perform the identification, indicate exposure rate, and neutron presence.

Using a DC power supply as a replacement for the batteries, reduce the applied voltage to the level that activates the low-battery indication. Increase the voltage until the low-battery indicator just turns off. Verify that the instrument operates by performing a simultaneous radionuclide identification using $^{241}$Am and $^{60}$Co within the manufacturer stated identification time or 2 min, whichever is shorter. The instrument shall also be tested using an unmoderated neutron source (neutron indication test). Document whether the instrument was able to perform the task.

d) Verify through review of the manual and direct observation of the instrument, and record the results.

e) Again verify through review of the manual and direct observation of the instrument, and record the results.

## 5.9 Effective range of measurement

### 5.9.1 Requirement

The effective gamma-ray energy response range shall be stated by the manufacturer, and should include the range from 25 keV to 3 MeV. The manufacturer shall also state the range for gamma-ray exposure rate measurement and for neutron count rate indication.

### 5.9.2 Test method

The manual shall be reviewed and the results recorded.

## 5.10 Spectral identification

### 5.10.1 Requirements

The following requirements shall be verified through the performance of the same ordered test methods listed in 5.10.2.

a) A display of the gamma-ray spectrum shall be available for review.

The instrument shall have the ability to store and transfer at least 50 complete (unprocessed) spectra. Each spectrum shall also contain collection and identification results information including:

— Time and date
— Identified radionuclides, categories, and associated confidence indications
— Spectrum integration time
— Measured gamma-ray exposure rate
— Neutron count rate at the time of measurement

NOTE—The data transfer format is defined in ANSI N42.42.

b) An indication shall be displayed or otherwise provided (i.e., “not identified”) if a radionuclide cannot be identified.

c) The manufacturer shall describe the meaning of reliability or confidence indications.

d) The instrument shall indicate if the exposure rate is too high or too low for radionuclide identification.

#### 5.10.2 Test method

a) Verify through review of the manual and direct observation of the instrument, and record the results.

   Verify the transfer and storage of data by performing 50 radionuclide identifications storing the results at the end of each identification process. Transfer the stored results to a computer. On the computer, verify that each individual spectrum contains the required information.

b) Verify through review of the manual, and record the results.

c) Verify through review of the manual, and record the results.

d) Indication that the exposure rate is too low for identification is verified through the performance of step 6.10. Indication that the exposure rate is too high for identification is verified through the performance described in 6.14.

### 5.11 Personnel protection alarm

An alarm shall be provided to alert the user that indicated exposure rates are above a user-selected threshold level. The alarm shall be both audible and visual and shall be adjustable through the restricted mode. The alarm shall have an "acknowledge" or other similar control to silence the audible function. It shall not be possible to switch off all alarm indicators at the same time.

#### 5.11.1 Requirement

An alarm shall be provided to alert the user that indicated exposure rates are above a user-selected threshold level. The alarm shall be both audible and visual, and shall be adjustable through the restricted mode. The alarm shall have an "acknowledge" or other similar control to silence the audible function. It shall not be possible to switch off all alarm indicators at the same time.

#### 5.11.2 Test method

The test shall be performed using the following technique.

Following instructions provided in the instrument manual, set the exposure rate alarm to activate at a level that is just above the ambient exposure rate. Cause the instrument to alarm using a gamma-ray emitting radiation source of sufficient strength. Silence the alarm and verify that the visual alarm remains active. If the system has a vibratory alarm, verify that the alarm operates as stated by the manufacturer.

### 5.12 Explosive atmospheres

#### 5.12.1 Requirements

The manufacturer shall state in its manual whether the instrument is certified for use in explosive atmospheres. If certification is claimed, documentation shall be provided by the manufacturer. Certification shall be based on UL-913-2002 [B3].

#### 5.12.2 Test method

The documentation provided by the manufacturer shall be reviewed. The documentation shall state whether or not the instrument is suitable for use in explosive atmospheres. A certificate of compliance shall be provided if the manufacturer states that the instrument may be used in explosive atmospheres. Compliance shall be based on testing done in accordance with UL-913-2002 [B3].

## 6. Radiological tests

### 6.1 General test information

Radiation sources or fields used for the following tests shall be traceable to NIST, according to ANSI N42.22.

The reference point of the instrument shall be placed at the point of measurement.

Unless stated otherwise, when exposure rates are required, the positioning of an instrument for testing shall be based on the exposure rate measurement from a calibrated gamma-ray measurement instrument, such as a microrem meter or ionization chamber.

The instrument shall be oriented with respect to the direction of the radiation source as indicated by the manufacturer.

If the instrument requires a background exposure rate measurement, it will be allowed to acquire the data in a manner specified by the manufacturer.

All identifications shall be performed within the time specified by the manufacturer or 2 min, whichever is less.

### 6.2 Response time

#### 6.2.1 Requirements

Significant changes in the measured exposure rate shall be indicated visually and shall be proportional to the exposure rate. A mutable audible indication proportional to the exposure rate shall also be available. The instrument shall indicate a change in exposure rate within 2 s.

#### 6.2.2 Test method

The test shall be performed using the following technique.

Expose the instrument to an increase in the ambient exposure rate of 50 μR/h ($^{137}$Cs) above the ambient background level over a time period that is ≤0.5 s. The instrument shall indicate an increase in exposure rate within 2 s. The displayed exposure rate indication shall be within ±50% of the new exposure rate within 5 s of the change.

Return the exposure rate to its original level; the instrument shall indicate a decrease in the exposure rate within 2 s. The displayed exposure rate indication shall be within ±50% of the changed exposure rate within 5 s of the change.

## 6.3 Gamma-ray exposure rate indication

### 6.3.1 Requirements

The relative intrinsic error in the response of the instrument to the reference exposure rate from $^{137}$Cs shall not exceed ±30% for exposure rates from 0.1 mR/h to the manufacturer-stated maximum response of the instrument.

### 6.3.2 Test method

The test shall be performed using $^{137}$Cs to produce exposure rates of 0.1 mR/h, 5 mR/h, and 80% of the manufacturer-stated maximum response. Record ten independent readings at each of the three exposure rates and calculate the mean value. The mean indicated exposure rate shall be within 30% of each applied exposure rate.

## 6.4 Alarms

### 6.4.1 Requirement

The instrument shall alarm when exposed to an exposure rate that is greater than the alarm threshold.

The test shall be performed using the techniques in 6.4.2 and 6.4.3.

### 6.4.2 Test method—gamma-ray

Set the alarm threshold to 1 mR/h and expose the instrument to a 2 mR/h exposure rate produced by $^{137}$Cs. The alarm shall activate within 3 s of the increased exposure.

### 6.4.3 Test method—neutron

Expose the instrument to a $^{252}$Cf neutron field that is equivalent to the flux emitted from an unmoderated $^{252}$Cf source with a fluence rate of $2 \times 10^4$ n/s ±20% (~0.01 µg) placed approximately 25 cm from the instrument. The neutron alarm shall activate within 2 s.

NOTE—A 0.01 µg $^{252}$Cf source placed approximately 25 cm from the instrument produces approximately 0.3 mrem/h.

## 6.5 Radionuclide identification

When identifying radionuclides, test results are considered acceptable when an instrument identifies the radionuclide(s) of interest, or that radionuclide(s) and expected daughter(s). It is considered not acceptable if the instrument identifies unexpected radionuclides or only the daughter(s) of the radionuclide(s) of interest.

If a library is used as part of the identification process, it shall contain the radionuclides listed in 6.5.1 for test purposes as a minimum, and it shall not be altered during the entire testing process.

Manufacturers shall specify which analysis modes are available for instrument operation. Some examples are:

a) Region summing
b) Peak fitting
c) Least-squares analysis of library spectra (both manufacturers and user supplied)
d) Automatic switching
e) Operation of user supplied spectral analysis software
f) Other manufacturer spectral analysis techniques

Test requirements shall be applied to each available mode, unless the instrument selects the analysis mode automatically.

### 6.5.1 Radionuclide categorization

The radionuclides of greatest interest and those most likely to be encountered are listed in four different categories.

NOTE—The following list should not be considered all-inclusive.

— *Special nuclear materials:* Uranium (used to indicate $^{233}$U, $^{235}$U), $^{237}$Np, Pu
— *Medical radionuclides:* $^{18}$F, $^{67}$Ga, $^{51}$Cr, $^{75}$Se, $^{89}$Sr, $^{99}$Mo, $^{99m}$Tc, $^{103}$Pd, $^{111}$In, Iodine ($^{123}$I, $^{125}$I, $^{131}$I), $^{153}$Sm, $^{201}$Tl, $^{133}$Xe
— *Naturally occurring radioactive materials (NORM):* $^{40}$K, $^{226}$Ra, $^{232}$Th and daughters, $^{238}$U and daughters
— *Industrial radionuclides:* $^{57}$Co, $^{60}$Co, $^{133}$Ba, $^{137}$Cs, $^{192}$Ir, $^{204}$Tl, $^{226}$Ra, and $^{241}$Am

### 6.5.2 Requirements

The manufacturer shall state the radionuclides that the instrument can identify and their category. The categories selected should be based on the list shown in 6.5.1.

The instrument shall display and store the identified radionuclide(s) and other information as specified in 5.10.

## 6.6 Single radionuclide

### 6.6.1 Requirements

The instrument shall be able to identify the following radionuclides within the time specified by the manufacturer with a maximum of 2 min. The manufacturer shall provide radionuclide-specific test results.

— *Unshielded:* $^{40}$K, $^{57}$Co, $^{60}$Co, $^{67}$Ga, $^{99m}$Tc, $^{125}$I, $^{131}$I, $^{133}$Ba, $^{137}$Cs, $^{192}$Ir, $^{201}$Tl, $^{226}$Ra, $^{232}$Th, $^{233}$U, $^{235}$U, $^{238}$U, Pu [Reactor grade plutonium (>6% $^{240}$Pu)], $^{241}$Am
— *Behind 5-mm steel shielding:* $^{40}$K, $^{57}$Co, $^{60}$Co, $^{67}$Ga, $^{99m}$Tc, $^{125}$I, $^{131}$I, $^{133}$Ba, $^{137}$Cs, $^{192}$Ir, $^{201}$Tl, $^{226}$Ra, $^{232}$Th, $^{233}$U, $^{235}$U, $^{238}$U, Pu [Reactor grade plutonium (>6% $^{240}$Pu)], $^{241}$Am

### 6.6.2 Test method

The test shall be performed using the following technique.

One at a time, expose the instrument to the radionuclides listed in 6.6.1. The gamma-ray exposure rate at the detector from each source, unshielded or shielded, shall be 50 μR/h. The test shall consist of ten trials for each radionuclide. The instrument shall be reset between each trial, if appropriate. The performance is acceptable when the instrument correctly identifies the radionuclide in eight out of ten consecutive trials.

## 6.7 Simultaneous radionuclide identification

### 6.7.1 Requirement

The instrument shall be able to identify a minimum of two radionuclides simultaneously.

### 6.7.2 Test method

The test shall be performed using the following technique.

Expose the instrument to $^{133}$Ba and Pu (reactor grade) simultaneously. Each radionuclide shall produce an exposure rate of approximately 50 μR/h at the detector. The test shall consist of ten trials. The performance is acceptable when the instrument correctly and simultaneously identifies both of the two test radionuclides in eight out of ten consecutive trials.

NOTE—If the Pu source used for these tests contains $^{241}$Am then the identification of $^{241}$Am is a correct ID.

## 6.8 Interfering ionizing radiation (gamma-rays)

### 6.8.1 Requirement

The instrument shall be able to identify the radionuclide of interest in the presence of an increased gamma-ray background from natural thorium.

### 6.8.2 Test method

The test shall be performed using the following technique.

Expose the instrument to a natural thorium $^{232}$Th gamma-ray exposure rate measured at the detector of 50 μR/h. Place a $^{241}$Am source at a location that provides an increase of 50 μR/h at the detector. The instrument shall be able to identify the radionuclide of interest ($^{241}$Am). The test shall consist of ten trials. The performance is acceptable when the instrument correctly identifies the radionuclide of interest in eight out of ten consecutive trials. The test shall be repeated using $^{60}$Co as the radionuclide of interest.

NOTE—The identification of $^{232}$Th together with the radionuclides of interest is correct unless a background update is performed after exposure to the $^{232}$Th source and before exposure to the $^{241}$Am and $^{60}$Co sources.

## 6.9 Interfering ionizing radiation (beta)

### 6.9.1 Requirement

The instrument shall identify a radionuclide of interest when exposed to the photons emitted from a shielded pure beta-emitting radionuclide.

### 6.9.2 Test method

The test shall be performed using the following technique:

Expose the instrument to a shielded beta emitter ($^{32}$P or $^{90}$Sr/$^{90}$Y). The photon (e.g., x-rays, bremmstrahlung) radiation shall be 50 μR/h at the detector. Expose the instrument to a 50 μR/h $^{137}$Cs gamma-ray exposure rate.

The test shall consist of ten trials. The performance is acceptable when the instrument correctly identifies $^{137}$Cs in eight out of ten consecutive trials.

Remove the $^{137}$Cs source and with the instrument exposed only to the shielded beta emitter, perform an identification. The identification results shall not include any unexpected radionuclides and should indicate the presence of a "not identified" radionuclide or "suspected beta emitter" in eight out of ten consecutive trials.

## 6.10 False identification

### 6.10.1 Requirement

The instrument shall not identify a radionuclide that is not present when operated in a stable and low ambient radiation background. An indication shall also be provided stating that the field is too low to perform an identification.

### 6.10.2 Test method

The test shall be performed using the following technique.

Perform a radionuclide identification with the instrument in a stable background of not more than 25 μR/h with no radiation sources present. A shielded box or enclosure may be required to perform the test. No unexpected radionuclides shall be identified. In addition, the instrument shall indicate that the field is too low to perform an identification. The indication may consist of a statement such as "move closer to the source." The test shall consist of ten trials and the performance is acceptable when the instrument does not identify a radionuclide in eight out of ten consecutive trials.

If naturally occurring radionuclides such as $^{40}$K are identified, actions should be taken to reduce or eliminate the source prior to performing the test. If the radionuclide is expected and cannot be removed, the test result shall be acceptable when the expected naturally-occurring radionuclide is identified.

## 6.11 Interference from surrounding material

### 6.11.1 Requirements

The instrument shall be able to identify radionuclides in the presence of backscattered radiation.

#### 6.11.2 Test method

The test shall be performed using the following technique.

Expose the instrument to a $^{137}$Cs source that produces a 500 µR/h exposure rate at the detector. The source shall be placed between a steel plate that is approximately 100 cm$^2$ (10 cm wide × 10 cm long) and 1 cm thick and the detector. The distance between the source and the steel plate shall be 10 cm.

This test is acceptable if $^{137}$Cs is correctly identified in eight out of ten consecutive trials.

### 6.12 Variation of identification based on angle of incidence

#### 6.12.1 Requirements

The identification of radionuclides shall be acceptable over incident angles from 0° to ±45º of the reference position.

#### 6.12.2 Test method

The test shall be performed using the following technique.

Expose the instrument to an $^{241}$Am source that provides an exposure rate of 50 µR/h at the detector at an incident angle of 0° and perform a radionuclide identification. Repeat the process with the incident angle at +45° and –45° in each of two orthogonal planes. Repeat the test using $^{60}$Co and $^{137}$Cs. The test shall consist of ten trials for each orientation and the performance is acceptable when the instrument correctly identifies each radionuclide in eight out of ten consecutive trials.

### 6.13 Neutron response

#### 6.13.1 Requirement

The instrument shall indicate the presence of neutron radiation. If the instrument responds in count rate, no further testing other than that stated in 6.4.3 is required.

If the instrument provides a dose equivalent rate response, the response shall be linear over its range and within ±50% of the CVT.

#### 6.13.2 Test method, dose equivalent rate only

The test shall be performed using neutron fields that are equivalent to 20%, 50%, and 80% of the manufacturer-stated response range. The mean-indicated dose equivalent rate shall be within 50% of each dose equivalent rate.

### 6.14 Over-range characteristics for identification

#### 6.14.1 Requirements

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

### 6.14.2 Test method

The test shall be performed using the following technique.

Increase the ambient exposure rate using $^{137}$Cs to 90% of the maximum exposure rate for radionuclide identification as stated by the manufacturer and perform a radionuclide identification. The instrument shall correctly identify $^{137}$Cs in eight out of ten trials.

## 6.15 Determination of full-energy-peak efficiency

### 6.15.1 Requirement

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

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

### 6.15.2 Test method

The test shall be performed using the following technique.

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 and collect a spectrum until a minimum of 10 000 net counts are obtained. Determine the full-energy-peak efficiency, as seen in Equation (1), for each source by:

$$\eta_a = 100\frac{A}{N_s} \tag{1}$$

where

$\eta_a$ is the absolute counting efficiency (%)
A is the net count rate in the full-energy-peak (includes subtraction of background spectrum)
$N_s$ is the total number of photons per second of the given energy emitted by the source during the counting time (source activity times the emission probability)

Record the efficiency, the system-stated full-energy-peak value, and its associated channel number on the test data sheet.

## 6.16 Determination of full width-half maximum (FWHM)

### 6.16.1 Requirement

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

### 6.16.2 Test method

The test shall be performed using the following technique.

Obtain a spectrum using the guidance found in step 6.15 and calculate the FWHM. Record the results in percent on the data sheet for each detector if multiple detectors are used. The determined FWHM shall be within ±20% of the manufacturer-stated FWHM.

## 6.17 Over-range characteristics for exposure rate indication

### 6.17.1 Requirements

The instrument shall indicate that an over-range condition exists when the ambient exposure rate is greater than the manufacturer-stated maximum exposure rate.

### 6.17.2 Test method

The test shall be performed using the following technique.

Using $^{137}$Cs expose the instrument to a step change in the exposure rate from ambient to two times the manufacturer-stated maximum exposure rate. The instrument shall indicate that an over-range condition exists within 5 s of the step change and shall remain in that condition for the entire exposure period (minimum of 5 min). After a minimum of 5 min, reduce the exposure rate to the pretest value. The instrument shall operate normally within 30 min.

## 6.18 Neutron indication in the presence of photons

### 6.18.1 Requirements

The neutron indication shall be insensitive to gamma radiation at gamma-ray exposure rates up to the manufacturer-stated maximum gamma-ray exposure rate.

The instrument shall not indicate neutron radiation in the presence of gamma radiation.

### 6.18.2 Test method

The test shall be performed using the following technique.

Increase the ambient gamma-ray exposure rate using a $^{137}$Cs source to the manufacturer-stated maximum exposure rate level. There shall be no indication of neutron radiation.

With the instrument exposed to the gamma-ray source, expose the instrument to a neutron field as described in 6.4. The instrument shall indicate the presence of neutron radiation.

# 7. Environmental performance requirements

## 7.1 Ambient temperature influence

### 7.1.1 Requirements

The instrument shall be operational at temperatures from –20 °C to +50 °C.

### 7.1.2 Test method

The test shall be performed using the following technique.

With the instrument powered from an external power source, switch the instrument on and place it in an environmental chamber. Allow the chamber and instrument to stabilize at 22 °C for a period of 2 h. During the last 30 min of the stabilization period, perform a ten-trial simultaneous radionuclide identification of $^{241}$Am and $^{60}$Co placed in a location that provides an indicated exposure rate of 50 μR/hr (from each source), and verify that the instrument responds to an unmoderated $^{252}$Cf neutron source. In addition, record ten exposure rate readings, and determine and record the mean value.

Remove the source and increase the temperature in the chamber at a rate of 10 °C /h to +50 °C. At each 10 °C (30 °C and 40 °C) increment, stabilize the temperature for a period of 1.5 h. During the last 30 min of each stabilization period, re-expose the instrument to the radiation sources (gamma-ray and neutron) and perform a ten-trial simultaneous radionuclide identification, record ten exposure rate readings, determine and record the mean value, and verify that the instrument responds to the unmoderated $^{252}$Cf neutron source. The $^{241}$Am and $^{60}$Co source shall be placed in a location that provides an indicated exposure rate of 50 μR/hr from each source. The sources shall be removed during each temperature ramp cycle.

At the high temperature limit of +50 °C, the instrument shall be exposed for a period of 8 h with exposure rate readings recorded and a 10-trial radionuclide identification performed during the last 30 min of the 8 h period. The neutron response shall also be tested during this period.

This same process shall be performed for temperatures that are less than the reference temperature of 22 °C. The 10 °C intervals are 10 °C, 0 °C, and −10 °C and the lower temperature limit is −20 °C. The test at −20 °C shall be the same as that performed at +50 °C.

The test is considered acceptable when the mean exposure rate readings remain with ±15% of the mean exposure rate obtained at 22 °C. The instrument shall also correctly identify each radionuclide in eight out of ten consecutive trials or at a ratio that is the same as or better than that obtained at 22 °C (For example, if the ten trial results at 22 °C are correct in six out of ten trials, the results at each test point shall be six or more correct). In addition, no alarms shall be activated due to temperature changes alone (no source present) and the instrument shall respond to an unmoderated neutron source.

## 7.2 Temperature shock

### 7.2.1 Requirements

The instrument shall be fully functional within one hour of exposure to rapid temperature changes from 22 °C to –20 °C, –20 °C to 22 °C, 22 °C to 50 °C, and 50 °C to 22 °C with each change being made in less than 5 min. The instrument shall provide an indication if it is not fully functional.

### 7.2.2 Test method

The test shall be performed using the following technique.

With the instrument powered from an external power source, switch the instrument on and place it in an environmental chamber. Allow the chamber and instrument to stabilize at 22 °C for 1 h. Perform a simultaneous radionuclide identification of $^{241}$Am and $^{60}$Co placed in a location that provides an exposure rate of 50 μR/hr (from each source) at the detector, and verify that the instrument responds to an unmoderated $^{252}$Cf neutron source.

The instrument and radioactive sources shall then be exposed to a temperature of 50 °C with the temperature change being made in less than 5 min.

The instrument shall be observed continuously. Every 15 min, a radionuclide identification consisting of three consecutive trials shall be performed as stated previously, and ten exposure rate readings shall be recorded. In addition, verify that the instrument continues to indicate the presence of a neutron source.

After 1 h, the instrument shall correctly identify each radionuclide in two out of three trials. In addition, the mean indicated gamma-ray exposure rate from each temperature extreme shall be within ±15% of the mean exposure rate obtained at 22 °C.

If the instrument is unable to perform a radionuclide identification after the first hour, an additional hour at the temperature is recommended with the time required for recovery noted.

If the instrument recovers within the first hour, data does not need to be taken during the second hour; however, the instrument should remain in this environment during the period to reach temperature stabilization.

Following the stabilization period, expose the instrument to a temperature of 22 °C ± 2 °C. This change shall be performed in less than 5 min and the analysis process stated above repeated.

The entire process shall be repeated for the 22 °C to −20 °C and −20 °C to 22 °C.

## 7.3 Relative humidity (RH)

### 7.3.1 Requirements

The instrument shall be fully functional over the range of humidity from 40% to 93% relative humidity (RH) at 35 °C.

### 7.3.2 Test method

The test shall be performed using the following technique.

With the instrument powered from an external power source, switch the instrument on and place it in an environmental chamber. Allow the chamber and instrument to stabilize at 22 °C and 40% relative humidity for 2 h. Perform a simultaneous radionuclide identification of $^{241}$Am and $^{60}$Co placed in a location that provides an exposure rate of 50 μR/hr (from each source) at the detector and verify that the instrument responds to an unmoderated $^{252}$Cf neutron source.

Increase the humidity at a rate not exceeding 10% RH per hour until attaining 93 ±3% RH, and the temperature at a rate not exceeding 10 ºC per hour to 35 °C. The humidity and temperature shall be maintained at these values for 16 h. A ten-trial radionuclide identification shall be performed and the mean

indicated gamma-ray exposure rate recorded during the last 30 min of this period. In addition, verify that the instrument responds to the unmoderated neutron source.

The humidity shall then be reduced to 40% at the rate stated previously while maintaining the temperature at 35 °C ±2 °C. After allowing the instrument to stabilize for a minimum of 2 h, a ten-trial radionuclide identification shall be performed and the mean indicated gamma-ray exposure rate recorded. In addition, verify that the instrument responds to the unmoderated neutron source.

At each test point, the instrument shall correctly identify each radionuclide in eight out of ten consecutive trials, or at a ratio that is the same as or better than the identification results obtained at 22 °C and 40% RH (for example, if the ten trial results at 22 °C and <50% RH are correct in six out of ten trials, the results at each test point shall be six or more correct). In addition, the mean indicated gamma-ray exposure rate from each test point shall be within ±15% of the mean exposure rate obtained prior to the humidity exposure, and the instrument shall indicate the presence of neutrons when exposed to the unmoderated neutron source.

## 7.4 Moisture and dust protection

### 7.4.1 Requirements

The instrument case design shall meet the requirements stated for IP Code 53 (see IEC 60529), which means that the instrument shall be protected from the ingress of dust and spraying water. For IP53, 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 sprayed at an angle up to 60º on either side of the vertical shall have no harmful effects.

### 7.4.2 Test method—dust

The test shall be conducted using a dust chamber (IEC 60529, Category 2) where the powder circulation pump may be replaced by other means suitable to maintain the talcum powder 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.

The instrument shall be exposed to a $^{137}$Cs source that is of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings. The instrument shall then be exposed to the dust environment for a period of 1 h. The instrument shall respond to the presence of radiation throughout the test and after the test.

Following exposure, an inspection shall be performed to determine the extent of dust ingress. Particular attention shall be made to the battery compartment and any other easily accessed portions of the instrument. 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 instrument. In addition, the mean indicated gamma-ray exposure rate at the end of the test shall be within ±15% of the mean exposure rate obtained prior to the exposure.

### 7.4.3 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 l/min ±5%, which should be kept constant during the test. The water temperature should not differ by more than 5 ºC from the temperature of the instrument under test. The test duration is 1 min/m$^2$ of the calculated surface area of the instrument with a minimum duration of 5 min.

Prior to the test, the instrument shall be exposed to a $^{137}$Cs source that is of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings. The instrument shall then be exposed to the water spray. The spray nozzle should be located approximately 2 m from the instrument. The

instrument shall respond to the presence of radiation throughout the test and after the test. In addition, the mean indicated gamma-ray exposure rate at the end of the test shall be within ±15% of the mean exposure rate obtained prior to the exposure.

The instrument shall be positioned such that the nozzle is directly pointed at the display. During the exposure, the orientation shall be changed by +60º and −60º in two orthogonal planes.

Following exposure, the instrument including the battery compartment shall be inspected to ensure that moisture did not penetrate into the instrument.

### 7.5 Cold temperature startup

#### 7.5.1 Requirement

The instrument shall be able to operate when switched on at the cold temperature limit (−20 ºC).

#### 7.5.2 Test method

The test shall be performed using the following technique.

Switch the instrument on and place it in an environmental chamber. Allow the chamber and instrument to stabilize at 22 °C for a period of 2 h. During the last 30 min of the stabilization period, perform a ten-trial simultaneous radionuclide identification of $^{241}$Am and $^{60}$Co placed in a location that provides an indicated exposure rate of 50 µR/hr (from each source), and verify that the instrument responds to an unmoderated $^{252}$Cf neutron source. In addition, record ten exposure rate readings, and determine and record the mean value.

Remove the sources from the chamber, switch the instrument off, and decrease the temperature in the chamber at a rate of 10 °C/h to −20 °C. Allow the temperature to stabilize for a period of 1.5 h. Switch on the instrument and after the manufacturer's specified warm-up period perform a ten-trial simultaneous radionuclide identification of $^{241}$Am and $^{60}$Co placed in a location that provides an indicated exposure rate of 50 µR/hr (from each source), and verify that the instrument responds to an unmoderated $^{252}$Cf neutron source. In addition, record ten exposure rate readings, and determine and record the mean value.

Remove the sources, switch off the instrument and return the temperature to 22 °C at a rate of 10 °C/h.

The test is considered acceptable if the mean exposure rate readings at −20 °C remain within ±15% of the mean exposure rate obtained at 22 °C, and the instrument correctly identified each radionuclide in eight out of ten consecutive trials or at a ratio that is the same as or better than that obtained at the nominal temperature.

## 8. Electromagnetic performance requirements

### 8.1 Electrostatic discharge (ESD)

#### 8.1.1 Requirement

The instrument shall be function properly during and after exposure to contact ESDs at intensities of up to 6 kV.

### 8.1.2 Test method

The test shall be performed using the following technique.

Prior to the test, perform a radionuclide identification of $^{241}$Am and $^{60}$Co placed in a location that provides an exposure rate of approximately 50 µR/h (from each) at the detector. Collect ten exposure rate readings and calculate the mean reading, standard deviation, and coefficient of variation. In addition, if the instrument has a neutron response capability, expose the instrument to the $^{252}$Cf source and record the response.

Remove the radiation sources, and expose the instrument to ESD. There shall be ten contact 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 instrument shall not alarm, change mode, or change indication (deviations exceeding ±15% of the initial mean gamma-ray or neutron readings) during exposure to the ESD.

Following the ESD test, verify that the instrument is able to perform a radionuclide identification of $^{241}$Am and $^{60}$Co placed in the same location that was used prior to the ESD test. In addition, record ten exposure rate readings and determine the mean value. The post-test mean instrument reading shall be within ±15% of pre-test mean reading, and the instrument shall indicate the presence of neutron radiation when exposed to the $^{252}$Cf source.

## 8.2 Radio frequency (RF) susceptibility

### 8.2.1 Requirement

The instrument should not be affected by RF fields over the frequency range of 80 MHz to 2500 MHz at an intensity of 10 volts per meter (V/m).

### 8.2.2 Test method

The test shall be performed using the following technique.

Without radiation test sources, expose the instrument to an RF field of 20 V/m 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 instrument'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.

Repeat the test with the instrument exposed to $^{137}$Cs and $^{252}$Cf positioned to provide a stable response on the instrument.

If susceptibilities are indicated by substantial changes in the indicated readings (deviations exceeding ±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 in three orientations relative to the emission source.

The results are acceptable if no alarms, spurious indications, or reproducible changes in response occur that exceed ±15% of the initial indicated value.

## 8.3 Radiated emissions

### 8.3.1 Requirement

RF emissions from an instrument shall be less than that which can interfere with other equipment located in the area of use. RF emissions when measured at 3 m shall be less than those shown in Table 2.

**Table 2—Radiated RF emission limits**

| Emission frequency range (MHz) | Field strength (microvolts/meter) |
|---|---|
| 30–88 | 100 |
| 88–216 | 150 |
| 216–960 | 200 |
| Above 960 | 500 |

### 8.3.2 Method of test

The test shall be performed using the following technique.

Place the instrument in a shielded room or chamber, as appropriate. Place an antenna 3 m from the assembly. With the instrument off, collect a background spectrum using a bandwidth of 50 kHz.

Switch the instrument on and perform a RF scan. Repeat the test with the instrument performing a radionuclide identification. RF emissions shall be less than those shown throughout the test.

## 8.4 Conducted immunity

### 8.4.1 Requirement

The instrument should not be affected by RF fields that can be conducted onto the instrument through an external conducting cable. Instruments that do not have at least one external conducting cable are excluded from this test.

### 8.4.2 Test method

The test shall be performed using the following technique.

Without the addition of radiation test sources, expose the instrument to a conducted RF field over the frequency range of 150 kHz to 80 MHz at an intensity of 140 dB (μV) 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 instrument's response time, but should not be less than 3 s.

Repeat the test with the instrument exposed to $^{137}$Cs and $^{252}$Cf that are positioned to provide a stable response on the instrument (COV <12%).

If susceptibilities are indicated by substantial changes in the indicated readings (deviations exceeding

±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.

The results are acceptable if no alarms, spurious indications, or reproducible changes in response occur that exceed ±15% of the initial indicated value.

### 8.5 Magnetic fields

#### 8.5.1 Requirements

The instrument should be fully functional when exposed to a constant DC magnetic field in three mutually orthogonal orientations relative to a 10 Gauss magnetic field.

#### 8.5.2 Test method

The test shall be performed using the following technique.

Without the addition of radiation test sources, expose the instrument to a 10 Gauss magnetic field.

Repeat the test with the instrument exposed to $^{137}$Cs and $^{252}$Cf that are positioned to provide a stable response on the instrument (COV <12%).

The results are acceptable if no alarms, spurious indications, or reproducible changes in response occur that exceed ±15% of the initial indicated value.

## 9. Mechanical performance requirements

### 9.1 Vibration

#### 9.1.1 Requirements

The instrument shall withstand exposure to vibrations associated with the operation of handheld or hand-carried equipment. The physical condition and functionality of the instrument shall not be affected by exposure (e.g., solder joints shall hold; nuts and bolts shall not come loose).

#### 9.1.2 Test method

The test shall be performed using the following technique.

Conduct an external examination (visual inspection) and ensure that the instrument is functioning properly. Subject the instrument to a random vibration at 0.01 $g^2$/Hz (spectral density) using 5 Hz and 500 Hz for the frequency endpoints.

Prior to the test, expose the instrument to a $^{137}$Cs gamma-ray source and $^{252}$Cf neutron source that provide sufficient exposure rates to produce a stable response on the instrument (COV <12%). Collect ten independent readings and calculate the mean reading, standard deviation, and coefficient of variation from each source type.

The instrument shall then be subjected to the vibration for a period of 1 h in each of three orthogonal orientations. After each 1 h vibration interval, re-expose the instrument to the same exposure rates used

prior to the test and determine the mean reading from ten independent readings for each source type. Each mean reading obtained after each vibration interval shall be within ±15% of the mean reading obtained prior to the test. After the test, inspect the instrument for mechanical damage and loose components. If internal inspection is not possible, check for loose components by gently shaking the instrument.

## 9.2 Mechanical shock

### 9.2.1 Requirements

The instrument shall withstand 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).

### 9.2.2 Test method

The test shall be performed using the following technique.

Conduct an external examination (visual inspection) and ensure that the instrument is functioning properly.

Prior to the test, expose the instrument to a $^{137}$Cs gamma-ray source and $^{252}$Cf neutron source that provide sufficient exposure rates to produce a stable response on the instrument (COV <12%). Collect ten independent readings and calculate the mean reading, standard deviation, and coefficient of variation from each source type.

Subject the instrument to ten pulses of peak acceleration of 50 g (half-sine-wave pulse), each applied for a nominal time interval of 18 ms in three orthogonal directions. After each set of ten shocks, re-expose the instrument in the same exposure rates used prior to the test and determine the mean reading from ten independent readings for each source type. Each mean reading obtained after each shock cycle shall be within ±15% of the mean reading obtained prior to the test. After the test, inspect the instrument for mechanical damage and loose components. If internal inspection is not possible, check for loose components by gently shaking the instrument.

## 9.3 Impact (microphonics)

### 9.3.1 Requirement

The instrument's response, both gamma-ray and neutron shall be unaffected by microphonic conditions, such as those that may occur from low intensity impacts from sharp contact with hard surfaces.

### 9.3.2 Test method

The test shall be performed using the following technique.

Switch on the instrument and allow it to warm up normally. Expose the instrument to a $^{137}$Cs gamma-ray source and $^{252}$Cf neutron source that provide sufficient exposure rates to produce a stable response on the instrument (COV <12%). Collect ten independent readings and calculate the mean reading, standard deviation, and coefficient of variation from each source type. Using an appropriate test device (i.e., spring hammer), expose the instrument case to three impacts at an intensity of 0.2 J. 0.2 J is equivalent to a mass of 0.2 kg moving at 1.4 m/s over a distance of 0.1 m (see IEC 60068-2-75). The test shall be performed on each side of the instrument case while observing the response. The instrument's response shall be unaffected (remain within ±15% of the pre-test values) by the impacts.

Remove the sources and expose the instrument case to ten impacts. The gamma-ray exposure rate shall remain stable, no neutrons shall be indicated, and no alarms or other functional changes shall occur due to the impacts.

## 10. Documentation

### 10.1 Certificate

A certificate shall accompany each hand held nuclide identifier, giving at least the following information:

a) Manufacturer's name or registered trademark
b) Type of the instrument and serial number
c) List of radionuclides to which the instrument was tested
d) Exposure rate range
e) Tests performed

### 10.2 Operation and maintenance manual

Each instrument shall be supplied with operating instructions, maintenance, and technical documentation.

# Annex A

(informative)

# Bibliography

## A.1 General

[B1] IEC 60068-2, Basic Environmental Testing Procedures—Part 2: Tests. [9]

[B2] IEEE Std C62.41™-1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits. [10, 11]

[B3] UL 913-2002, Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations. [12]

## A.2 Detectors

[B4] ANSI N42.12-1994, American National Standard Calibration and Usage of Thallium-Activated Sodium Iodide Detector Systems for Assay of Radionuclides. [13]

[B5] ANSI N42.13-2004, American National Standard Calibration and Usage of "Dose Calibrator" Ionization Chambers for the Assay of Radionuclides.

[B6] ANSI N42.14-1999, American National Standard for Calibration and Use of Germanium Spectrometers for the Measurement of Gamma-Ray Emission Rates of Radionuclides.

[B7] ANSI N42.31-2003 American National Standard for Measurement Procedures for Resolution and Efficiency of Wide-Bandgap Semiconductor Detectors of Ionizing Radiation.

[B8] IEEE Std 300™-1988, IEEE Standard Test Procedures for Semiconductor Charged-Particle Detectors.

[B9] IEEE Std 309™-1999/ANSI N42.3-1999 (Reaff 2006), IEEE Standard Test Procedures and Bases for Geiger-Mueller Counters.

[B10] IEEE Std 325™-1996 (Reaff 2002), IEEE Standard Test Procedures for Germanium Gamma-Ray Detectors.

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[9] 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 (www.ansi.org).

[10] The IEEE standards or products referred to in this annex are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

[11] IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[12] UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (http://global.ihs.com/).

[13] ANSI N42 publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

## A.3 Detection and identification instruments

[B11] ANSI N42.32-2006, American National Standard Performance Criteria for Alarming Personal Radiation Detectors for Homeland Security.

[B12] ANSI N42.33-2006, American National Standard for Portable Radiation Detection Instrumentation for Homeland Security.

[B13] ANSI N42.35-2006, American National Standard for Evaluation and Performance of Radiation Detection Portal Monitors for Use in Homeland Security.

[B14] IEC 62327:2006, Radiation Protection Instrumentation—Hand-held Instruments for the Detection and Identification of Radionuclides and for the Indication of Ambient Dose Equivalent Rate from Photon Radiation.

[B15] ISO 22188:2004, Monitoring for Inadvertent Movement and Illicit Trafficking of Radioactive Material.[14]

## A.4 Radiological protection instruments

[B16] ANSI N13.27-1981 (Reaff 1992), American National Standard Performance Requirements Pocket-Size Alarm Dosimeters and Alarm Ratemeters.

[B17] ANSI N42.17A-2004, American National Standard Performance Specifications for Health Physics Instrumentation—Portable Instrumentation for Use in Normal Environmental Conditions.

[B18] ANSI N42.17B-1989 (Reaff 2005), American National Standard Performance Specifications for Health Physics Instrumentation—Occupational Airborne Radioactivity Monitoring Instrumentation.

[B19] ANSI N42.17C-1989 (Reaff 2005), American National Standard Performance Specifications for Health Physics Instrumentation—Portable Instrumentation for Use in Extreme Environmental Conditions.

[B20] ANSI N42.20-2003, American National Standard Performance Criteria for Active Personnel Radiation Monitors.

[B21] ANSI N323A-1997, American National Standard Radiation Protection Instrumentation Test and Calibration—Portable Survey Instruments.

[B22] ANSI N323B-2003, American National Standard for Radiation Protection Instrumentation Test and Calibration—Portable Survey Instrumentation for Near Background Operation.

[B23] IEC 60395:1972, Portable X or Gamma Radiation Exposure Rate Meters and Monitors for Use in Radiological Protection.

[14] ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/ Suisse (http://www.iso.ch/). ISO 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/).

## A.5 Electromagnetic compatibility

[B24] FCC Rules, Code of Federal Regulations, Title 47, Parts 0–19.[15]

[B25] IEC 61000-6-2:1999, Electromagnetic Compatibility (EMC)—Part 6-2: Generic Standards—Immunity for Industrial Environments.

## A.6 Units, quantities, calibrations

[B26] ISO 4037-1:1996, X and Gamma Reference Radiation for Calibrating Dosemeters and Doserate Meters and for Determining their Response as a Function of Photon Energy—Part 1: Radiation Characteristics and Production Methods.

[B27] ISO 4037-2:1997, X and Gamma Reference Radiation for Calibrating Dosemeters and Doserate Meters and for Determining their Response as a Function of Photon Energy—Part 2: Dosimetry for Radiation Protection over the Energy Ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV.

[B28] ISO 8529-1:2001, Reference Neutron Radiations—Part 1: Characteristics and Methods of Production.

[B29] ISO 8529-2:2000, Reference Neutron Radiations—Part 2: Calibration Fundamentals Related to the Basic Quantities Characterizing the Radiation Field.

[B30] NIST SP 250-98 ED, NIST Calibration Services User's Guide, 1998 Edition.[16]

[15] 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/).

[16] NIST publications are available from the National Institute of Standards and Technology, NIST Public Inquiries, NIST, 100 Bureau Drive, Stop 3460, Gaithersburg, MD, 20899-3460, USA (www.nist.gov).

# Annex B

(informative)

## Detector tests

This standard and ANSI N42.32-2006 [B11], ANSI N42.33-2006 [B12]], and ANSI N42.35-2006 [B13] utilize some of the following types of detectors:

— *Sodium Iodide (NaI) scintillation detectors:* These detectors are available in large sizes such that they have both high efficiency and moderate energy resolution. They are operated at room temperature. Test procedures are given in ANSI N42.12-1994 [B4].

— *CZT semiconductor detectors:* CZT and other wide-bandgap semiconductor detectors are semiconductor detectors that can be operated at room temperatures. At this time they are small physically and therefore have low efficiency. They have good energy resolution though somewhat poorer than that of Germanium detectors. Standard test procedures for these detectors are given in ANSI N42.31-2003 [B7].

— *Germanium gamma-ray detectors:* These detectors have very high energy resolution and are currently of sufficient size to have also high efficiency. They must be operated at cryogenic temperatures. Test procedures for these detectors are given in IEEE Std 325-1996 [B10].

— *Semiconductor charged-particle detectors:* These detectors are capable of high resolution measurements of charged particles. Test procedures for these detectors are given in IEEE Std 300-1988 [B8].

— *Geiger-Mueller counters:* These are widely used for radiation detection and intensity measurements. They are avalanche detectors, the output signals of which are independent of the radiation energy. Test procedures for these detectors are given in IEEE Std 309-1999/ ANSI N42.3-1999 [B9].

— *Ionization chambers:* These are highly accurate detectors for gross measurement of radiation. They are operated at room temperature. Test procedures for these detectors are given in ANSI N42.13-1986 [B5].

— *Plastic scintillator detectors:* These detectors are particularly useful for portal monitors. Standards and standard measurement procedures have not yet been developed.

# Annex C

(informative)

## Sample user interface evaluation technique

### Controls

| | | |
|---|---|---|
| 1. | Was the on/off switch easy to find? | Y/N |
| 2. | Were all the controls labeled? | Y/N |
| 3. | Were all the labeled controls easy to read/interpret? | Y/N |
| 4. | Were all the controls easy to operate without gloves? | Y/N |
| 5. | Could all the controls be operated with gloves? | Y/N |

### Interface

| | | |
|---|---|---|
| 6. | Was brightness/contrast adjustable, either manually or automatically, to compensate for light levels? | Y/N |
| 7. | Was everything readable in low light levels | Y/N |
| 8. | Was everything readable in high light levels | Y/N |
| 9. | Did the display contain abbreviations or icons? (If no, skip next question.) | Y/N |
| 10. | Were the abbreviations or icons easy to interpret or understand? | Y/N |
| 11. | Was the time and date displayed? | Y/N |

### Operation

| | | |
|---|---|---|
| 12. | Did the instrument convey it's state-of-health at start-up (e.g., battery life, detector present and working, memory available, mode of operation)? | Y/N |
| 13 | Did you have to refer to the instruction manual more than once to complete the test? | Y/N |
| 14. | Was the menu structure simple and intuitive? | Y/N |
| 15. | At any time during the test did the instrument prompt you for action? | Y/N |
| 16. | Did the instrument issue any cautions or warning? (If no, go to question 17) | Y/N |
| 17. | Did the instrument provide information on the nature of the cautions or warning and a corresponding course of action? | Y/N |