IEEE Standards

ANSI N42.17A-2003
(Revision of
ANSI N42.17A-1989)

N42.17A

American National Standard for Performance Specifications for Health Physics Instrumentation–Portable Instrumentation for Use in Normal Environmental Conditions

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

IEEE

Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

29 April 2004

Print: SH95202
PDF: SS95202

American National Standard for Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Normal Environmental Conditions

Sponsor

National Committee on Radiation Instrumentation, N42

Accredited by the

American National Standards Institute

Secretariat

The Institute of Electrical and Electronics Engineers, Inc.

Approved 29 September 2003

American National Standards Institute

Abstract: This standard establishes the minimum performance criteria for health physics instrumentation for use in ionizing radiation fields. Testing methods are included to establish the acceptability of each type of instrumentation.
Keywords: health physics, instrumentation, normal environment, portable survey, survey

---

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Print: ISBN 0-7381-3910-6 SH95202
PDF: ISBN 0-7381-3911-4 SS95202

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic reviews and users are cautioned to obtain the latest editions.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken to affirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Introduction

(This introduction is not part of ANSI N42.17A-2003, Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Normal Environmental Conditions.)

This standard is the responsibility of the Accredited American National Standards Institute Committee on Radiation Instrumentation, N42, which delegated its development to Subcommittee N42.RPI on Radiological Protection Instrumentation. N42 was the balloting group and approved the standard on N42 letter ballot of 23 December 2002.

Participants

At the time this standard was approved, the Accredited Standards Committee on Radiation Instrumentation, N42 had the following members:

Louis Costrell, *Chair*
Michael P. Unterweger, *Vice Chair*
Sue Vogel, *Administrative Secretary*

Organization Represented	*Name of Representative*
American Conference of Governmental Industrial Hygienists	Jesse Lieberman
Bartlett Services	Morgan Cox
Battelle Northwest Laboratories	Joseph C. McDonald
Bicron	Joseph G. Bellian
Chew, M.H.	Jack M. Selby
Commerce Dept, U.S. NIST	Michael P. Unterweger
	Louis Costrell *(Alt.)*
Consultant	Frank X. Masse
Eberline Instruments	Mitchell Truitt
Entergy-ANO	Ron Schwartz
Femo-TECH Inc.	Richard Straub
Gamma-Metrics	Ernesto A. Corte
General Activities Inc.	Karl Reinitz
Health Physics Society	Joseph R. Stencel
Institute of Electrical and Electronics Engineers, Inc.	Louis Costrell
	Julian Forster *(Alt.)*
	Anthony J. Spurgin *(Alt.)*
	Michael P. Unterweger *(Alt.)*
Lawrence Berkeley National Laboratory	Edward J. Lampo
Lawrence Livermore National Laboratory	Gary Johnson
NASA, GFSC	H. Sachidananda Babu
Nuclear Standards Unlimited	Al N. Tschaeche
Oak Ridge National Laboratory	Peter J. Chiaro, Jr.
	Charles L. Britton *(Alt.)*
ORTEC Corp.	Ronald M. Keyser
Overhoff Technology Corp.	Mario W. Overhoff
Swinth Associates	Kenneth L. Swinth
Tennelec	Larry Darken
Tennessee, University of	William M. Bugg
Thermo-electron	Richard P. Oxford
Translucent	G. Laurie Miller
Wisconsin Public Service Group	Timothy Martinson
Individual Members	Edward Fairstein
	Paul L. Phelps
	Lee J. Wagner

At the time this standard was approved, Subcommittee N42.RPI had the following members:

Jack M. Selby, *Chair*

Joseph G. Bellian	Joseph G. Johnson	Joseph C. McDonald
Peter J. Chiaro, Jr.	Michelle L. Johnson	Richard P. Oxford
Morgan Cox	R. L. Kathren	Carl R. Siebentritt
Henry Fong	Mike Lantz	Al N. Tschaeche
Robert Ford	Sergio Lopez	Ed Walker
Mark M. Hoover	Jimmy Little	Chuan-Fu Wu

At the time this standard was approved, the ANSI 42.17A Working Group had the following members:

Peter Chiaro, Jr., *Chair*

Laird C. Bean	Michelle Johnson	Kevin Reaves
Dru Carson	Cyndi Jones	Scott Rogers
Clare Grehofsky	Gary Labruyere	Dale Snowder
	Riasp Medora	

Contents

1. Scope 1

1.1 Introduction 1

2. References 2

3. Definitions 4

4. General test procedures 6

4.1 Applicability of tests 6
4.2 Standard test conditions 6
4.3 Statistical fluctuations 6

5. General characteristics 7

5.1 Units of readout 7
5.2 Scaling factors 8
5.3 Ease of decontamination 8
5.4 Moisture protection 8
5.5 Alarm threshold 8
5.6 Markings 9
5.7 Battery status indication 9
5.8 Protection of switches 9
5.9 Zero set 10
5.10 AC power 10
5.11 Battery power 10
5.12 Battery power indicator 10
5.13 AC-powered instruments with battery backup 11

6. Electronic and mechanical requirements and tests 11

6.1 Circuit verification 11
6.2 Alarms 11
6.3 Response stability 12
6.4 Geotropism 12
6.5 Response time 13
6.6 Coefficient of variation 14
6.7 Line noise susceptibility 14
6.8 Electrostatic discharge (ESD) 15

7. Radiation response 15

7.1 Accuracy 15
7.2 Probe surface sensitivity 16
7.3 Photon energy dependence 17
7.4 Beta energy dependence 18
7.5 Neutron energy dependence 19
7.6 Photon radiation overload 20
7.7 Angular dependence 20

8. Interfering response 21

8.1 Extracameral response 21
8.2 Radio frequency (RF) 21
8.3 Conducted immunity 22
8.4 Magnetic fields 22
8.5 Interfering ionizing radiation 23

9. Environmental factors 24

9.1 Temperature 24
9.2 Temperature shock 24
9.3 Humidity 25
9.4 Mechanical shock 26
9.5 Vibration 26
9.6 Ambient pressure 26

10. Documentation 27

10.1 Operation and maintenance manual 27
10.2 Type test report 27

Annex A (informative) Bibliography 28

Annex B (informative) Tests performed with variation of influence quantities 29

American National Standard for Performance Specifications for Health Physics Instrumentation-Portable Instrumentation for Use in Normal Environmental Conditions

1. Scope

This standard establishes the minimum performance criteria for health physics instrumentation for use in ionizing radiation fields. Testing methods are included to establish the acceptability of each type of instrumentation. This standard does not specify which instruments or systems are required, nor does it consider the number of specific applications of such instruments.

1.1 Introduction

The object of this standard is to provide basic performance requirements and verification test methods for *portable instruments used in normal environmental conditions* for radiation protection of personnel.

As used in this standard, health physics instrumentation provides direct readout of, or readout related to, dose and dose-equivalent rate, or activity-per-unit area (i.e., effective probe area). Included are portable rate and integrating devices for beta, photon, and neutron radiation and monitors for surface contamination (alpha, beta, and photon). Instruments used to measure the presence of low-energy beta emitters (i.e., less than 200 keV maximum energy) are not addressed in this standard. Personnel dosimeters; instruments designed to be used as individual or personal monitors, or warning devices; environmental monitoring instruments; and air monitors are outside the scope of this standard. Special purpose instrumentation, such as emergency post-accident radiological monitors, may also fall under the scope of one or more related ANSI standards. This standard is intended to supplement rather than replace these.

In general, health physics instrumentation is considered to cover the dose and dose-equivalent rate ranges for survey meters of 0.1 mrad/h to 1000 rad/h (1 μGy/h to 10 Gy/h) and 0.1 mrem/h to 1000 rem/h (1 μSv/h to 10 Sv/h). It covers activity-per-unit-area ranges for surface contamination monitors of 50 disintegrations per minute (dpm)/cm^2 to 10^4 dpm/cm^2 (0.83 Bq/cm^2 to 167 Bq/ cm^2) for beta/photon radiation and 1dpm/ cm^2 to 10^4 dpm/cm^2 (0.02 Bq/cm^2 to 167 Bq/cm^2) for alpha radiation.

For specific characteristics, test requirements will vary with the use of the instrument. For example, the requirements for a laboratory instrument are not as demanding as requirements for an instrument to be used in an uncontrolled environment. Table B.1 lists the characteristics in the standard and the associated clause where the requirements and test can be found.

This standard specifies general characteristics; general test procedures; radiation characteristics; and electrical, mechanical, safety, and environmental characteristics. Throughout this standard, three verbs have been used to indicate the degree of rigor intended for each specific criterion. The word *shall* is used to denote a requirement, the word *should* to denote a recommendation, and the word *may* to denote a permissible practice.

If the operational conditions for an instrument are less severe than the requirements of this standard, then the instrument manufacturer and the purchaser may agree upon the instrument performance specifications; however, the instrument should be tested using the testing protocol of this standard.

2. References

This standard shall be used in conjunction with the following publications:

ANSI Z540.2-1997, U.S. Guide to the Expression of Uncertainty in Measurement.[1]

ICRU Report 12, Certification of Standardized Radioactive Sources, 1968.[2]

ICRU Report 20, Radiation Protection Instrumentation and Its Application, 1971.

ICRU Report 39, Determination of Dose Equivalents Resulting from External Radiation Sources, 1985.

ICRU Report 43, Determination of Dose Equivalents from External Radiation Sources—Part 2, 1988.

ICRU Report 47, Measurement of Dose Equivalents from External Photon and Electron Radiations, 1992.

ICRU Report 57, Conversion Coefficients for Use in Radiological Protection Against External Radiation, 1998.

ICRU Report 60, Fundamental Quantities and Units for Ionizing Radiation, 1998.

IEC 61187-1993, Electrical and electronic measuring equipment—Documentation.[3]

IEEE Std C62.41-1991, IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits.[4,5]

---

[1]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[2]ICRU publications are available from the National Council on Radiation Protection and Measurements, 7910 Woodmont Avenue, Suite 800, Bethesda, MD 20814, USA.

[3]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.

[4]The IEEE standards or products referred to in Clause 2 are trademarks owned by the Institute of Electrical and Electronics Engineers, Incorporated.

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

ISO Guide to the Expression of Uncertainty in Measurement, 1993 rev., ISBN 92-67-10188-9.[6]

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.

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 8 keV to 1,3 meV and 4 meV to 9 meV.

ISO 4037-3:1999, X and gamma reference radiation for calibrating dose meters and doserate meters and for determining their response as a function of photon energy—Part 3: Calibration of area and personal dosemeters and the measurements of their response as a function of energy and angle of incidence

ISO 6980:1984, Reference Beta Radiations for Calibrating Dosimeters and Doseratemeters and for Determining Their Response as a Function of Beta Radiation Energy.

ISO 6980-2:2000, Reference beta radiations for calibrating dosimeters and doserate meters and for determining their response as a function of beta-radiation energy.

ISO 8529-1:2001, Neutron reference radiations for calibrating neutron-measuring devices used for radiation protection purposes and for determining their response as a function of neutron energy.

ISO 8529-2:2000, Radiation protection—Reference neutron radiations, Part 2: Calibration fundamentals related to the basic quantities characterizing the radiation field.

ISO 8769-2:1996, Reference sources for the calibration of surface contamination monitors—Beta-emitters (maximum beta energy greater than 0,15 MeV) and alpha-emitters.

ISO 10647:1996, Procedures for calibrating and determining the response of neutron-measuring devices used for radiation protection purposes.

ISO/IEC 17025:1999, General requirements for the competence of testing and calibration laboratories.[7]

NCRP Report 50, Environmental Radiation Measurements, 1976.[8]

NCRP Report 57, Instrumentation and Monitoring Methods for Radiation Protection, 1978.

NCRP Report 58, A Handbook of Radioactivity Measurements Procedures, 2nd ed., 1985.

NCRP Report 112, Calibration of Survey Instruments Used in Radiation Protection for the Assessment of Ionizing Radiation Fields and Radioactive Surface Contamination, 1991.

---

[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, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[7]ISO/IEC 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/IEC publications are also available in the United States from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/). Electronic copies are available in the United States from the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[8]NCRP publications are available from the National Council on Radiation Protection and Measurements, 7910 Woodmont Avenue, Suite 800, Bethesda, MD 20814, USA.

Shleien, Bernard, Lester A. Slaback, Jr., and Brian Birky, eds., *Handbook of Health Physics and Radiological Health,* 3rd ed., Lippincott Williams & Wilkins, 1998.[9]

3. Definitions

For the purpose of this standard, the following definitions apply:

3.1 acceptable source: Source of radiation that meets the specification in ICRU report 12.

NOTE—See Table 4.

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

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

3.4 accuracy: The degree of agreement of the observed value with the conventionally true value of the quantity being measured.

3.5 adjust: To alter the response by means of a variable, built-in control such as a potentiometer.

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

3.7 angular dependence: Response of the detector as a function of the angle of incidence of the radiation being detected and a reference orientation.

3.8 calibrate: **(A)** To adjust or determine the response or reading of an instrument relative to a series of conventionally true values. **(B)** To determine the activity of a radiation source relative to a standard or conventionally true value.

3.9 coefficient of variation: The standard deviation, expressed as a percentage of the mean [i.e., standard deviation $(\bar{x}) \bullet (100)$].

3.10 contamination meter: An assembly, including one or several radiation detectors and associated subassemblies, designed to measure radioactivity-per-unit surface area associated with the contamination of the examined object.

3.11 conventionally true value of a quantity: The commonly accepted best estimate of the value of that quantity. This and its associated uncertainty will normally 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 measurement quality assurance (MQA) with the National Institute of Standards and Technology (NIST).

3.12 decade: A range of values for which the upper response limit is a power of ten above the lower limit.

3.13 detection axis: A specific imaginary line through the effective center of the detector to which the radiation field direction can be referenced.

3.14 detection limit: The minimum (lower detection limit) or maximum (upper detection limit) radiation level that can be quantifiably measured by the instrument.

[9]This publication available from www.amazon.com.

3.15 detector: A material or device that produces a signal suitable for measurement or analysis.

3.16 dose: A generic term that means absorbed dose or dose equivalent as appropriate.

3.17 dose equivalent: The product of the absorbed dose, quality factor, and all other necessary modifying factors at the point of interest in tissue. The units of dose equivalent are the rem and sievert (Sv).

3.18 dose rate: The radiation dose delivered per unit of time measured in rem or Sv per hour.

3.19 drift: Change in readout, usually gradual, without concomitant change in the influence quantity.

3.20 effective center: The point within a detector that produces, for a given set of irradiation conditions, a response equivalent to that which would be produced if the entire detector were located at the point.

3.21 effective energy: The energy used to characterize a heterogeneous radiation field that behaves under specified conditions as it were a monoenergetic radiation field of the same energy.

3.22 energy dependence: A change in instrument response with respect to radiation energy for a constant dose equivalent or dose-equivalent rate.

3.23 evaluation: Interpretation of measurements and observations, including determination of compliance with applicable specifications.

3.24 extracameral: Pertaining to that portion of the instrument exclusive of the detector.

3.25 geotropism: A change in instrument reading with a change in instrument orientation as a result of gravitational effects.

3.26 homogeneity coefficient: The ratio of the first to second half-value layers; usually applied to a heterogeneous X-ray beam.

3.27 indicated value: A scale or decade reading or displayed value.

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

3.29 overload response: An instrument’s response when exposed to radiation intensities greater than its upper limit.

3.30 photon: Ionizing electromagnetic radiation, irrespective of origin.

3.31 portable: An instrument that is capable of being carried by hand to a specific facility or location for use and usually less than 22.5 kg.

3.32 portable survey meter: An instrument intended to be operated while being carried by a person.

3.33 precision: The degree of agreement of repeated measurements of the same parameter.

3.34 probe sensitivity: The response of a given probe to a uniform area source.

3.35 rad: Unit of absorbed dose.

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

3.37 reading: The indicated value of the readout.

3.38 readout: The device that conveys visual information regarding the measurement to the user.

3.39 reference orientation: The orientation in which the instrument is normally intended to be operated as stated by the manufacturer, or the position of the source in relation to the detector.

3.40 response: The instrument indication produced as a result of some influence 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 (i.e., signal) at the detector.

3.42 scale: A subrange of the total range of measurement.

3.43 standard (instrument or source): (1) National standard—An instrument, source, or other system or device maintained and promulgated by NIST or an equivalent international laboratory. (2) Transfer standard—A physical measurement standard that has been compared directly or indirectly with the national standard. This standard is typically a measurement instrument or a radiation source used as a laboratory standard. (3) Laboratory standard—An instrument, source, or other system or device calibrated by comparisons with a standard other than a U.S. national standard.

3.44 subassembly: An assembled unit designed to be incorporated with other units in a finished product.

3.45 test: A procedure whereby the instrument, component, or circuit is evaluated for satisfactory operation.

3.46 type testing: Evaluation or measurement of all identified performance characteristics of a representative sample of production model instruments.

3.47 uncertainty: The estimated bounds of the deviation from the mean value, generally expressed as a percent of the mean value. Ordinarily taken as the sum of (1) the random errors at the 95% confidence level and (2) the estimated upper limit of the systematic error.

3.48 useful energy range: The set or range of continuous energies for a specific type of radiation in which the instrument meets specified criteria.

4. General test procedures

4.1 Applicability of tests

Tests to determine compliance with the specifications given in Clause 5, Clause 6, Clause 7, Clause 8, and Clause 9 are provided after each specification.

4.2 Standard test conditions

Acceptable ranges for environmental conditions during testing are given in Table 1 and shall be met except where the effect of the condition itself is being tested.

4.3 Statistical fluctuations

For any test involving radiation, the measurement uncertainty associated with each test should be evaluated. This measurement uncertainty shall be such that the result of the test may be determined with sufficient

precision to demonstrate compliance or noncompliance with the test requirement. ANSI Z540.2-1997 or the ISO Guide to the Expression of Uncertainty in Measurement should be used to establish measurement uncertainties.

Table 1—Standard test conditions

Influence quantities	Acceptable range for standard test conditions
Warm-up time	< 10 min, or as stated by the manufacturer
Relative humidity	< 65%
Ambient temperature	20 °C to 24 °C
Atmospheric pressure	70 kPa to 106 kPa
Line voltage[a]	Nominal voltage ± 1%
Frequency[b]	60 Hz ± 0.5 Hz
Angle of incidence of radiation	Direction stated ± 5°
Background radiation	25 µrem/hr (0.25 µSv/hr)
Nonionizing electromagnetic field of external origin	Less than the lowest value that causes interference
Magnetic induction of external origin	Less than twice the induction due to the Earth's magnetic field
Controls	Set up for normal operation
Contamination by radionuclides	Negligible
Reference point	As stated by the manufacturer

[a]Applicable only to ac-powered instruments.
[b]See Footnote a.

5. General characteristics

5.1 Units of readout

5.1.1 Requirements and test specifications

Readings of beta-photon dose and dose-rate instruments should be expressed in units of dose (i.e., rad, Gy, or multiples or submultiples thereof) or dose rate (e.g., rad/h, Gy/h). Readings of photon exposure and exposure rate instruments may be expressed in units of exposure (i.e., R or multiples or submultiples thereof) or exposure rate (i.e., R/h). Alternatively, the units of dose equivalent may be used. Readings of neutron monitoring instruments shall be in units of dose equivalent (e.g., rem or Sv) or dose-equivalent rate (e.g., rem/h or Sv/h).

For contamination monitoring instruments, the units should be in counts or activity-per-unit time (dpm, dps, Bq). Conversion factors (i.e., efficiency factors) are typically used to convert counts to activity. The conversion can be done manually by the operator or automatically by the instrument, depending on the type of instrument used. Readout units shall be indicated on the instrument's display.

Verify by inspection.

5.2 Scaling factors

5.2.1 Requirements and test specifications

For an instrument with linear scales, the scaling factor between adjacent scales shall be a single integer multiple that does not exceed 10.

If a logarithmic scale is provided with switched measurement scales, there shall be an overlap between adjacent scales, and it should be one decade.

The instrument shall indicate the scale and measurement units for each scale; if a floating decimal point is used, it shall be displayed.

Verify by inspection.

5.3 Ease of decontamination

5.3.1 Requirements and test specifications

The instrument should be constructed to facilitate decontamination. A smooth, nonporous external surface free from crevices is suggested. Penetrations through the exterior case should be constructed to minimize the ingress of contamination.

Verify by inspection.

5.4 Moisture protection

5.4.1 Requirements and test specifications

The manufacturer shall state design features or other precautions for instruments designed to be resistant to moisture.

Verify by inspection.

5.5 Alarm threshold

5.5.1 Requirements and test specifications

For instruments equipped with an alarm feature, the value of alarm threshold shall be given either as a percent of scale or decade of adjustment or in terms of the units of the display. Alarm thresholds shall be protected from inadvertent adjustment or editing.

Verify by inspection.

5.6 Markings

5.6.1 Requirements and test specifications

5.6.1.1 General

All external instrument controls, displays, and adjustments shall be identified as to function. Internal controls shall be identified through markings on circuit boards and identification in technical manuals.

Each requirement shall be verified by inspection.

5.6.1.2 Exterior markings

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

1) Manufacturer and model number,
2) Unique serial number,
3) Location of the effective center(s) or area(s) of detection,[10] and
4) Function designation for controls, switches, and adjustments.

Markings shall be easily readable and permanently fixed under normal conditions of use (including use of normal decontamination procedures).

5.6.1.3 Readout markings

Analog displays shall be provided with scale markings. For linear analog readouts, major scale divisions shall be at 0% and 100% of full scale and at 3 to 12 equally spaced points in-between (e.g., 0.2, 0.4, 0.6, and 0.8 of full scale). Logarithmic scales shall have each decade marked, with at least 4 but not more than 12 approximately equally spaced (e.g., 1, 1.5, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10) major division markings between the limits of the decade. Minor scale divisions should be provided where appropriate to increase the resolution of the instrument readings.

5.7 Battery status indication

5.7.1 Requirements and test specifications

Battery-powered instruments shall be equipped with a test circuit or other visible direct indicator of battery condition for each battery circuit.

Verify by inspection.

5.8 Protection of switches

5.8.1 Requirements and test specifications

Switches and other controls should be protected to curb inadvertent deactivation or improper operation of the instrument.

Verify by inspection.

[10]Surface contamination monitors are exempt from this requirement. For instruments where the effective center cannot be physically marked, guidance on the location shall be given by the manufacturer in the operation manual.

5.9 Zero set

5.9.1 Requirements and test specifications

If a control for setting zero (i.e., null balancing of circuit) or indication of zero is available to the operator, it shall function correctly in the presence of radiation fields. This requirement does not apply to a mechanical zero adjustment.

To verify that the requirement is met, the instrument shall be exposed to ionizing radiation of sufficient intensity to produce an upscale response. During exposure, the zero control shall be operated to ensure that the reading can be adjusted to zero and that the response is stable.

5.10 AC power

5.10.1 Requirements and test specifications

The operating power requirements shall be stated by the manufacturer and shall include the operating voltage range and current.

Verify by inspection.

5.11 Battery power

5.11.1 Requirements

The manufacturer shall state battery lifetimes and battery-associated operating temperature requirements. The manufacturer shall also state the minimum voltage required for satisfactory operation of the instrument. The minimum voltage is defined as that voltage where there is a < 10% change in instrument response compared to the response with fresh batteries.

The low-battery indication shall be no lower than the minimum voltage as defined above.

5.11.2 Test

The instrument shall be equipped with fresh batteries. All functional circuits (alarms and speakers excluded) shall be switched on and shall remain on during the test. The detector shall be exposed to ionizing radiation of sufficient intensity to produce a stable instrument response. A sufficient number of readings shall be taken in accordance with 4.3 after the manufacturer recommended warm-up period and every hour thereafter. The battery lifetime shall be where the ratio of the mean reading relative to the mean reading taken after the warm-up period falls outside the interval 0.9 to 1.1.

5.12 Battery power indicator

5.12.1 Requirements

The mean instrument reading shall be within 10% of the mean reading obtained with fresh batteries when the low-battery indicator activates.

5.12.2 Test

The batteries shall be replaced by a stable dc-power supply set to produce a voltage equivalent to the voltage produced by a set of fresh batteries. The instrument shall be exposed to ionizing radiation sufficient in

intensity to produce a stable response. A set of reference readings shall be taken in accordance with 4.3. The voltage shall be decreased until the low-battery indicator activates. Another set of readings shall then be taken, and the mean of the readings shall be compared to the initial mean reference reading.

5.13 AC-powered instruments with battery backup

5.13.1 Requirements

AC-powered instruments equipped with rechargeable batteries that must be charged to provide proper operation shall be provided with markings located near the low-battery indicator to warn the user that improper operation will result until the battery is recharged. When the low-battery indicator activates, the mean instrument reading shall be within 10% of the mean reading obtained with properly charged batteries. In addition, the instrument shall meet the requirements of 5.10 and 5.11.

5.13.2 Test

The instrument shall be inspected for the low-battery indicator and required markings related to the improper operation warning. The instrument shall be equipped with freshly recharged batteries. All functional circuits shall be switched on and shall remain on during the test. (If alarms and speakers are not activated, this procedure is equivalent to the one used during the battery power test, and this data may be obtained during that test.) The instrument shall be operated using battery power only. The detector shall be exposed to ionizing radiation of sufficient intensity to provide a stable response. A sufficient number of readings shall be taken in accordance with 4.3. Readings shall be taken after the manufacturer-recommended warm-up period and when the low-battery indicator activates. The mean instrument reading obtained when the low-battery indicator activates shall be compared to the mean instrument reading obtained after the warm-up period.

6. Electronic and mechanical requirements and tests

6.1 Circuit verification

6.1.1 Requirements

Audit and test circuits and audio indicators, automatic or manual, are recommended.

6.1.2 Test

Tests shall be performed based on manufacturer’s specifications to determine compliance.

6.2 Alarms

6.2.1 Requirements

Instruments may be provided with various audible or visual alarms that operate in one of the following modes:

a) Latching—remain activated until manually reset (i.e., acknowledged), or
b) Nonlatching—clear automatically on reduction of radiation level to below the alarm level.

Alarms shall normally continue to operate in radiation fields greater than the selected alarm points; however, it should be possible to interrupt the audible alarm by deliberate action without interrupting the visual alarm.

If an “acknowledge” or mute facility is provided, it should automatically reset when the alarm condition ceases.

Each alarm threshold shall be designed to allow operational verification by means of test signals, radioactive sources, or signal input circuitry.

The range of adjustment shall be specified and the value of the alarm activation threshold shall be capable of being adjusted to any point within this range. It shall not be possible to incapacitate the alarm by any means such as setting the alarm thresholds beyond range limits.

6.2.2 Tests

6.2.2.1 Latching and nonlatching reset

The detector shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to activate both audible and visual alarms, and these shall be observed for at least 5 min in the alarm condition. If it is possible to interrupt the audible alarm by deliberate action without interrupting the visual alarm, this action shall be performed and the result observed.

Latching alarms shall remain activated for at least 5 min after the radiation source is removed, and the meter indication or readout shall fall to background. An acknowledge or reset switch or function shall deactivate a latched alarm.

Nonlatching alarms shall deactivate and the readout shall fall to background after the radiation source is removed.

6.3 Response stability

6.3.1 Requirements

An instrument's response shall remain stable for a period of at least 20 days. Stability is indicated when an instrument's response is within 5% of the response at the end of the 20-day test cycle.

6.3.2 Test

Instruments shall be operated continuously and in a fixed geometry for the first 24 h of the response stability test, and periodically for the remaining 19 days. Instruments shall be switched on and allowed to stabilize. The detector shall be exposed in a reproducible geometry to ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. A set of readings shall be taken every hour for the first 8 h, at the end of 24 h, once per day for the first five days, and then periodically for the next 14 days. The mean from each set of readings shall be compared to the reference response.

6.4 Geotropism

6.4.1 Requirements

A change in the mean instrument reading caused solely by change in spatial orientation of survey meters shall be within 5% of the mean reading obtained with the instrument in the reference orientation. This requirement is not appropriate for nonmechanical displays.

6.4.2 Test

The detector shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The instrument shall be rotated both horizontally and vertically relative to a flat surface with the source attached or without affecting the source to detector geometry. A sufficient number of readings shall be taken in accordance with 4.3 at each 90° increment and the means calculated. The mean readings shall be compared to the mean of a reference set of readings obtained in the reference orientation to determine compliance.

6.5 Response time

6.5.1 Requirements

The time required for an instrument to respond to, and recover from, a step change in radiation levels from 10% to 90% (90 to 10%) of the radiation level that is equivalent to 80% of each range shall be stated by the manufacturer. Response times for dose rates that are ≥1 rad, rem, or R per hour shall be < 2 seconds. Maximum response times based on an increase in dose rate are stated in Table 2.

If the response time is adjustable through the use of a switch or potentiometer, the response time determined at each extreme position of the control shall be stated. If the response time is controlled through data entry, the response time(s) shall be stated based on settings that are equivalent to each manufacturer-recommended extreme setting.

Contamination instruments shall be tested using a pulse generator for ranges with maximum indications of less than 500 cpm (or equivalent activity).

Table 2—Instrument response time vs. scale or decade

Scale or decade maximum		
Beta-photon instruments (rad/h or rem/h)	**Neutron instruments (rem/h)**	**Maximum response time (s)**
$> 10^{-4}$ to $\leq 10^{-3}$	$< 5 \times 10^{-2}$	30
$> 10^{-3}$ to $\leq 10^{-2}$	5×10^{-2} to ≤ 1	10
$> 10^{-2}$ to $\leq 10^{-1}$	> 1	5
$> 10^{-1}$ to ≤ 1		3
> 1		2

6.5.2 Test

The instrument shall be exposed to an activity level that is equivalent to approximately 80% of the range under test. A sufficient number of readings shall be obtained in accordance with 4.3 to determine the mean value. The radiation field shall be removed quickly and the instrument reading shall be allowed to stabilize at the pre-exposure reading. The original radiation field shall be renewed and the time determined for the instrument reading to move from 10% to 90% of the previously established mean reading. The source shall be removed and the time determined for the instrument to move from 90% to 10% of the pre-exposure reading. These two steps shall be repeated until a sufficient number of data points have been obtained in accordance with 4.3 (typically 10). This test shall be repeated for each range of use.

6.6 Coefficient of variation

6.6.1 Requirements

Instruments with a nonadjustable response time shall provide a stable response when exposed to a radiation field that is ≥ 75% of the range under test. The response is considered stable when the coefficient of variation, determined from a series of 10 consecutive readings, is ≤ 12%.

If the response time is adjustable, the coefficient of variation shall be determined with the instrument set in the "slow" response time (see 6.5 for additional information regarding response time). Contamination instruments shall be tested using a pulse generator for ranges with maximum indications of less than 500 cpm (or equivalent activity).

Instruments with single ranges that cover many decades (> 10) shall be tested at two points within each range. The point selected shall be stated and shall be between 25% and 50% of the range under test.

6.6.2 Test

The instrument shall be exposed in a reproducible geometry to a radiation source (see Table 3) of sufficient intensity to produce a reading that is approximately 80% of the range under test. Ten successive readings shall be taken with the time interval between readings being not less than that corresponding to three times the response time for the range on which readings are made. The mean, standard deviation, and coefficient of variation of the instrument readings shall then be calculated. This test shall be repeated for each range of the instrument.

If the instrument uses single ranges that cover > 10 decades, the test shall be repeated at a point that is between 25% and 50% of the range under test.

Table 3—Acceptable reference sources for performance tests[a]

Radiation type	Acceptable sources[b]
Alpha	^{230}Th, ^{239}Pu, ^{241}Am
Beta	^{99}Tc, ^{36}Cl, ^{90}Sr-^{90}Y, ^{204}Tl Series 1 Sources (ISO 6980-1984); ^{Nat}U or depleted uranium in equilibrium with daughters filtered through 7 mg/cm^2 of material with $Z \leq 13$. Exposure to be made at a distance of ≤ 2 cm from the source to the detector window.
Photon	^{137}Cs filtered to remove ≥ 90% of the betas and associated Ba X-rays; ^{60}Co filtered to remove ≥ 90% of the betas.
Neutron	^{252}Cf, ^{238}PuBe, ^{239}PuBe, D_20 moderated ^{252}Cf, ^{241}AmBe

[a]Other than energy dependence tests, reference sources for these tests are listed under the specific tests.
[b]Sources and certifications shall be traceable to the NIST or meet the specifications in ICRU Report 12-1968.

6.7 Line noise susceptibility

6.7.1 Requirements

The mean instrument response of ac-powered units shall be within 15% of the mean reference reading during or after subjugation to voltage sags, surges, and transients on the power line. Sags, surges, or transients shall not trigger system alarms.

6.7.2 Test

The detector shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The mean instrument response shall be determined. If the instrument is equipped with an alarm, it shall be set 15% higher than the mean reading.

Pulses should be applied to the mains supply terminals via a coupling/decoupling network, or equivalent equipment.

Ten pulses shall be applied to the instrument with a minimum time between surges of one minute. Each pulse should consist of a combination wave (1.2/50 μs - 8/20 μs) at an intensity of 2 kV. Ring wave pulses should be not more than 2 kV.

6.8 Electrostatic discharge (ESD)

6.8.1 Requirements

The contact-discharge technique shall be used for conductive surfaces and coupling planes and the air-discharge technique for insulating surfaces. Discharge points shall be selected based on user accessibility. Response effects should be < 15% of the response without the discharge. No alarms or other outputs should be activated when the meter or monitor is exposed to the discharge.

6.8.2 Test

Ten discharges per discharge point with a minimum of one-second recovery time between each discharge. The maximum intensity of each discharge is based on the technique used; 6 kV for contact discharge and 8 kV for air discharge.

7. Radiation response

7.1 Accuracy

7.1.1 Requirements

The ratio of the mean indicated value to the conventionally true value shall fall within the range 0.90 to 1.10 or, as shown in Equation (1):

$$0.90 \leq \frac{\bar{r}_i}{CTV_{ref}} \leq 1.10 \qquad (1)$$

where

$\bar{r}_i$ is the mean indicated value,

CTV_{ref} is the conventionally true value of the reference radiation.

7.1.2 Tests

7.1.2.1 Photon dose-rate instruments

The detector shall be exposed in a reproducible geometry to (an) acceptable reference source(s) of known intensity to produce a mean reading at approximately 25% and 75% of each scale or decade. A sufficient number of readings shall be taken in accordance with 4.3, and the ratios of the mean observed values to the conventionally true values determined for each point. The reference sources shall be specified by the instrument manufacturer (see Table 3).

7.1.2.2 Count-rate instruments and contamination monitors

The count-rate portion of the instrument shall be tested with a pulse generator at two points on each scale or decade to assure that the count-rate response is linear within 3% of the input value. These points should be at approximately 20% and 80% of the scale or decade. In addition, the instrument shall be tested with a minimum of two different source intensities, one of which shall be approximately mid-scale or mid-decade on the most sensitive scale or decade. The second source should be approximately 10 times the intensity of the first source. The detector system shall meet the accuracy requirements specified in 7.1.1.

7.1.2.3 Beta and neutron dose-rate instruments

At a minimum, beta and neutron dose-rate instruments shall be exposed in a reproducible geometry to an acceptable reference source of known intensity that produces an average reading at approximately 25% to 75% of the scale or decade. A sufficient number of readings shall be taken in accordance with 4.3. Beta dose rate shall be stated in terms of absorbed dose rate at 7 mg/cm^2 depth in tissue.

7.2 Probe surface sensitivity

7.2.1 Requirements

The manufacturer shall state the surface sensitivity of the probe used in conjunction with a particular counter. The surface sensitivity, S_s, shall be expressed in counts per seconds or minutes and/or activity per unit squared.

The radionuclides for which the surface sensitivity has been measured shall be specified.

The radiation sources should represent the type and energy of radiation that is anticipated and of interest to the particular facility. In accordance with international standards, many source manufacturers quote 2π activities (surface emission rates) for alpha and beta sources and 4π (absolute activities) for alpha, beta, and gamma sources. Emission rates are typically reported in terms of _/sec or _/sec. Activity is quoted in Curie, Becquerel, and/or dpm.

The user should be aware of differences in backscatter and self-absorption effects of the source and surface to be monitored when the efficiency is determined using a source's 4π emission rate. If these values are unknown or inconsistent, the source's surface emission rate should be used for surface monitoring instrumentation. When calculating activity-based alarm set points using the surface emission rate, the efficiency should be multiplied by 0.5 or divided by 2.

When calibrating instruments for volumetric contamination levels, sources should be placed within objects that provide typical scatter and shielding effects to determine detector efficiency using the 4π emission rate.

7.2.2 Test

The surface sensitivity of the probe to alpha radiation shall be measured using a uniformly distributed alpha source, such as ^{239}Pu, ^{241}Am, or ^{230}Th, with an area at least as large as the face of the probe, if possible. The surface activity shall be known with an accuracy compatible with that of the measurements.

If the area of the detector is greater than the area of the source, multiple readings shall be taken at the center and along each corner or the outer edge of the sensitive area of the detector. The active area of the source must be over the sensitive area of the detector for this test. A sufficient number of instrument readings shall be taken in accordance with 4.3.

The alpha source shall be placed at a distance from the face of the probe to be indicated by the manufacturer, but which should in no case exceed 10 mm.

The surface sensitivity of the probe to beta radiation shall be measured in the same manner.

The surface sensitivity of the beta probe should be checked with at least three beta emitters, whose maximum energies are distributed as follows:

1) One ≥ 0.2 and ≤ 0.4 MeV,
2) One between 0.4 MeV and 1 MeV, and
3) One ≥ 1 MeV.

At a minimum, the surface sensitivity shall be checked with a ^{90}Sr-^{90}Y source.

7.3 Photon energy dependence

7.3.1 Requirements

The useful energy range for photon dose-rate measuring instruments shall be stated by the manufacturer and shall be at least 80 keV to 1.25 MeV. It shall be based on the range of energies where the following conditions are met (the manufacturer shall state the energy used as the reference energy), as shown in Equation (2):

$$0.8 \leq \frac{(\bar{r}_{en_i} / CTV_{en_i})}{(\bar{r}_{ref} / CTV_{ref})} \leq 1.2 \qquad (2)$$

where

$\bar{r}_{en_i}$ is the mean indicated reading to photon radiation of energy *i*,

$\bar{r}_{ref}$ is the mean indicated reading to the reference photon radiation,

CTV_{en_i} is the conventionally true value of the photon radiation of energy *i*,

CTV_{ref} is the conventionally true value of the reference photon radiation.

For instruments designed for energies outside this range, the manufacturer shall state the useful energy range.

7.3.2 Test

Photon energy dependence may be measured on any scale or decade providing that the effect of the statistical fluctuations of the instrument readings is minimized and that a complete series of measurements is made for each detector in the instrument. A sufficient number of instrument readings shall be taken in

accordance with 4.3. The instrument shall be exposed to the source in the reference orientation and should also be exposed in an orientation perpendicular to the reference orientation. Photon energy dependence shall be determined by comparing the mean indicated value at a specific energy to that of the conventionally true value of the radiation field at that energy.

For energies below 300 keV, the exposure shall be made at a series of effective energies in approximately 40 keV increments ranging from approximately 20 keV_{eff} to 250 keV_{eff}. The lower limit of the useful energy range of the instrument shall be determined by measurement and shall be equal to the lowest effective energy at which the response was measured, provided the responses to all effective energies tested at and above this level fall within the requirements of 7.3.1. X-ray spectra used shall have a homogeneity coefficient of ≥ 0.8. Acceptable sources are described in Table 4. These X-ray techniques are combinations of tube potential and filtration specified by the NIST. A type of energy dependence curve showing response as a function of energy and identifying the measurement points clearly shall be prepared and included with the documentation described in Clause 10.

Table 4—Acceptable reference X-ray sources for the photon energy dependence test

Nominal effective energy (keV)	Technique, reference (US NIST)
20	M30
40	H50
80	H100
120	H150
166	H200
211	H250
252	H300

7.4 Beta energy dependence

7.4.1 Requirements

The energy range for beta dose or dose-rate monitoring instruments shall be stated and should be at least 0.2 MeV to 3.5 MeV (E_{max}). At a given beta energy within this stated range, the ratio of the mean indicated value to the conventionally true value shall fall within 0.5 to 1.5 for maximum beta energies between 0.50 MeV and 3.5 MeV and should fall within 0.5 to 1.5 for maximum beta energies between 0.2 MeV and 3.5 MeV; thus, as shown in Equation (3):

$$0.5 \leq \frac{(\bar{r}_{\beta_i} / CTV_{\beta_i})}{(\bar{r}_{\beta_{ref}} / CTV_{\beta_{ref}})} \leq 1.5 \quad (3)$$

where

$\bar{r}_{\beta_i}$ is the mean indicated reading to beta radiation of energy *i*,

$\bar{r}_{\beta_{ref}}$ is the mean indicated reading to the reference beta radiation,

CTV_{β_i} is the conventionally true value of the beta radiation of energy *I* absorbed dose rate at 7 mg/cm^2 depth in tissue),

$CTV_{\beta_{ref}}$ is the conventionally true value of the reference beta radiation (absorbed dose rate at 7 mg/cm^2 depth in tissue).

The instrument manufacturer shall specify the reference energy source.

7.4.2 Test

Beta energy dependence may be measured on any scale or decade provided the effect of the statistical fluctuations of the instrument readings is minimized and that a complete series of measurements is made for each detector. The detector shall be exposed to each of the beta fields specified. A sufficient number of instrument readings shall be taken in accordance with 4.3. The mean indicated value shall be determined and divided by the conventionally true value for each of the sources specified below or by an NIST equivalent:

^{90}Sr-^{90}Y, ^{204}Tl, ^{147}Pm (Series 1 sources, ISO 6980-1984)

The photon dose contribution from these sources shall be minimized during the measurement procedure and should not exceed 10% of that from the beta dose contribution (ISO 6980-1984, Series 1 sources are assumed to be acceptable). Appropriate corrections should be made to the conventionally true values.

7.5 Neutron energy dependence

7.5.1 Requirements

The useful energy interval for neutron dose equivalent and dose-equivalent rate instruments shall be stated. Within this stated interval, the ratio of the indicated mean obtained from a source of energy *i* compared to that obtained from readings obtained from the reference energy source shall be within 0.5 to 2.0, with the reference energy source specified by instrument manufacturer; thus, as shown in Equation (4):

$$0.5 \leq \frac{(\bar{r}_{n_i} / CTV_{n_i})}{(\bar{r}_{n_{ref}} / CTV_{n_{ref}})} \leq 2.0 \tag{4}$$

where

$\bar{r}_{n_i}$ is the mean indicated reading to neutron radiation of energy *i*,

$\bar{r}_{n_{ref}}$ is the mean indicated reading to the reference neutron radiation,

CTV_{n_i} is the conventionally true value of the neutron radiation of energy *i*,

$CTV_{n_{ref}}$ is the conventionally true value of the reference neutron radiation.

7.5.2 Test

Neutron energy dependence may be performed on any scale or decade provided the effect of the statistical fluctuations of the instrument readings is minimized and that a complete series of measurements is made for each detector. The useful energy range and the sources used to establish that range shall be stated by the manufacturer. Table 5 provides a list of acceptable sources. The detector shall be exposed in a reproducible geometry to each of the neutron fields selected at sufficient intensity to minimize the effect of the statistical fluctuations on the instrument readings and to produce a response of approximately mid-scale or mid-decade.

Neutron response shall be measured under low scatter conditions. Either the total neutron scatter contribution regardless of origin shall not exceed 15% of the dose-equivalent rate or appropriate corrections shall be made to the readings and the corrections documented.

Table 5—Reference sources for neutron energy dependence

Energy range	Acceptance sources
Thermal	Highly moderated, sealed (0.025 eV) radionuclide source or reactor thermal column Cd/In ratio ≥ 10
Intermediate	D_2O moderated (15 cm) ^{238}PuBe, (0.5 eV to 10 keV) ^{239}PuBe, ^{241}AmBe, or ^{252}Cf
Fast	Unmoderated radionuclide sources (10 keV to 10 MeV)(^{238}PuBe, ^{239}PuBe, ^{241}AmBe, PuLi, and AmLi)
Fission spectrum	Unmoderated ^{252}Cf
14 MeV	^{3}H(D,n) ^{4}He reaction

7.6 Photon radiation overload

7.6.1 Requirements

When exposed to radiation levels greater than that corresponding to the highest scale or decade maximum, the instrument shall continue to operate. The readout of an analog instrument shall be off scale or decade at the higher end of the scale or decade and shall remain so until the radiation field is reduced to below full scale or decade value. Digital readouts shall convey that the radiation level exceeds the upper detection limit of the instrument in a manner described by the instrument manufacturer. When the radiation field is removed, the instrument reading shall return to the expected value within 2 min.

7.6.2 Test

The detector shall be exposed to an appropriate radiation field with a conventionally true value of 100 times the upper detection limit for limits up to and including 10 rd/h (0.1 Gy/h) or 10 times the upper detection limit for limits greater than 10 rd/h (0.1 Gy/h), with a minimum exposure rate of 1000 rd/h (10 Gy/h) to be used. The response shall be observed for 1 min. Observations shall be made on the highest scale or decade. The radiation field shall be removed, and the instrument response shall be observed for 2 min.

7.7 Angular dependence

7.7.1 Requirements

The mean response of an instrument to a photon radiation incident at any angle not exceeding 45º from the direction of maximum response of the instrument shall be not less than 80% of this maximum response. At an angle of 90º from the direction of maximum response, the mean instrument reading shall be not less than 50% of the maximum response. These requirements apply for at least two representative photon energies.

The mean response of an instrument to a beta radiation incident at any angle ≤ 45º from the direction of maximum response of the instrument should be ≥ 50% of this maximum response.

The instrument manufacturer shall state the angular response of an instrument to neutron radiation. These requirements apply to exposure and exposure rate, to dose and dose rate, and to dose equivalent and dose-equivalent rate instruments; no test is required for alpha or beta contamination monitoring instruments.

7.7.2 Test

The detector or instrument shall be placed in a uniform radiation field emanating from a single source of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The instrument or field direction shall be rotated in each of three mutually orthogonal planes around the effective center and the mean scale or decade reading determined at ≤ 45° increments in each plane with respect to the direction of maximum response. A sufficient number of instrument readings shall be taken at each increment in accordance with 4.3. For photon radiation, this test shall be made with the energies from a ^{137}Cs reference source (Table 3) and a source with an effective energy below 130 keV. If the instrument does not meet the requirements below 130 keV, then the manufacturer shall state the lowest energy at which the instrument can meet the angular dependence requirement. For neutron radiation, the manufacturer shall state the source used. For beta radiation, the ^{90}Sr-^{90}Y reference source given in Table 3 shall be used.

8. Interfering response

8.1 Extracameral response

8.1.1 Requirements

Extracameral response for photon or beta-photon dose-rate instruments and neutron dose-equivalent rate instruments that have an external detector that can be considered separate from the rest of the unit shall be < 5% (upscale or downscale) of the intensity of the exposing field up to a maximum intensity equal to the scale or decade in use.

There shall be no detectable extracameral response in contamination survey instruments from external ambient beta-photon fields ≤ 1 rd/h (i.e., instrument response shall be not greater than 5% of the mean background reading).

8.1.2 Test

For photon and beta-photon dose-rate instruments and neutron dose-equivalent rate instruments, all portions of the instrument except the detector shall be exposed to fields equal to approximately full scale or full decade of each scale or decade and the response observed. A sufficient number of instrument readings shall be taken in accordance with 4.3. The detector shall remain in the circuit during this test, but it may be physically isolated or shielded such that the direct radiation level is ≤ 0.05 that of the radiation field on the remainder of the instrument (a collimated source is acceptable). Beta-photon surface contamination instruments shall be exposed in the same manner to photon fields of 1 rd/h from ^{137}Cs. Appropriate reference sources from Table 3 shall be used.

8.2 Radio frequency (RF)

8.2.1 Requirements

When exposed to an 80% amplitude modulated (1 kHz) RF field at frequencies from 20 MHz to 1000 MHz, and 1800 and 2450 MHz at 10 V/m, response effects shall not exceed 10% of the response without the field present. No alarms or other outputs shall be activated when the meter or monitor is exposed to the field.

NOTE—Some level of susceptibility may be acceptable. The user should determine the critical frequencies.

8.2.2 Test

The instrument shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The source selected shall not interfere with the RF field. Expose the instrument to a frequency scan from 20 MHz to 1000 MHz, and 1800 and 2450 MHz at an intensity of 20 V/m measured without an instrument present in the irradiation area.

NOTE—20 V/m is chosen to reduce test time. The required field intensity is 10 V/m. If tested at this level, the item will have to be tested in multiple orientations. When 20 V/m is used, the test is only required in one orientation.

If, during the scan, operational susceptibilities are observed, the frequencies of susceptibility should be noted. The instrument should then be retested at an intensity of 10 V/m. If the instrument can be used in different orientations, the test shall be performed on all sides using the 10 V/m intensity. The test should be performed using an automated sweep at a rate not greater than 1.5×10^{-3} decades per second or 1% of the fundamental.

8.3 Conducted immunity

8.3.1 Requirements

This test applies to instruments that may be used in the presence of RF transmitters in the frequency range of 150 kHz to 80 MHz. Meters and monitors that do not have at least one conducting cable (mains supply, signal line, or earth connection) are excluded.

Response effects should be ≤ 10% of the response without the field present. No alarms or other outputs should be activated when the meter or monitor is exposed to the field.

NOTE—Some level of susceptibility may be acceptable. The user should determine the critical frequencies.

8.3.2 Test

The instrument shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade.

The exposure frequency range shall be 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 rate not greater than 1.5×10^{-3} decades per second, or 1% of the fundamental.

8.4 Magnetic fields

8.4.1 Requirements

The mean instrument response, obtained when the instrument is exposed to a magnetic field that is 800 A/m (~10 Oe), shall be ≤ 15% of the mean instrument response obtained when no magnetic field is present. Alternatively, the manufacturer shall specify that the instrument may be sensitive to and not properly operate in such fields.

8.4.2 Test

The instrument shall be positioned in a magnetic field generation system with the field at zero intensity. The instrument shall be exposed in a reproducible geometry to an acceptance source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to

produce a response of approximately mid-scale or mid-decade. The mean instrument reading shall be determined after a sufficient number of instrument readings are taken in accordance with 4.3. The instrument shall then be exposed to a magnetic field that is 800 A/m (~10 Oe) in intensity, and the mean instrument reading shall be determined again. The instrument/probe shall be rotated 90º relative to the magnetic field and the exposure repeated.

If the magnetic field exposure system is such that a zero-field intensity cannot be produced, the radiation-exposure geometry shall be documented and reproduced later in another location and the mean instrument reading without the field determined after the exposure to the magnetic field.

8.5 Interfering ionizing radiation

8.5.1 Requirements

An instrument shall not exhibit a response greater than that stated by the manufacturer to radiation other than the type of radiation for which it is designed. Interfering radiation limits are shown in Table 6.

Table 6—Response to interfering radiation

Radiation(s) measured by Instrument	Alpha	Beta[a]	Neutron photon[b]	(n)[c]
_	—	1 rd/h	1 rd/h	1 rem/h
_ + _	—	—	1 rd/h	1 rem/h
_ + _ + photon	—	—	—	1 rem/h
_[d,e]	10^4 dpm/cm^2	—	10 rd/h	1 rem/h
_ + photon[f]	10^4 dpm/cm^2	—	—	1 rem/h
_ + photon + n	10^4 dpm/cm^2	—	—	—
Photon	10^4 dpm/cm^2	10 rd/h	—	1 rem/h
Photon + n	10^4 dpm/cm^2	10 rd/h	—	—
n	10^4 dpm/cm^2	10 rd/h	10 rd/h	—

[a]External ambient fields.
[b]See Footnote a.
[c]See footnote a.
[d]For thin window (i.e., ≥10 mg/cm^2) detectors, interference as specified by the instrument manufacturer from alpha particles is permitted.
[e]For beta-scintillation detectors, interference as specified by the instrument manufacturer from low-energy photons is permitted.
[f]See Footnote d.

8.5.2 Test

These measurements shall be made with the instrument switched on and operating in its most sensitive range. The instruments shall be exposed to an acceptable reference source from Table 7 at the levels specified in Table 6, and the response recorded.

Table 7—Reference sources for interfering ionizing radiation

Radiation type	Acceptable reference source
Alpha	^{230}Th, ^{239}Pu
Beta	^{90}Sr-^{90}Y (ISO 6980-1996)
Photon	^{137}Cs filtered to remove ≥ 90% of the betas and associated Ba X-rays
Neutron	^{252}Cf (unmoderated), PuBe

9. Environmental factors

9.1 Temperature

9.1.1 Requirements

The manufacturer shall state the temperature range over which the mean instrument response remains within 15% of the mean response at 22 °C.

The mean instrument response over the temperature range from 0 °C to 40 °C shall be within 15% of the mean response determined at 22 °C.

The mean instrument response over the temperature range from –10 °C to 0 °C and 40 °C to 50 °C shall be within 20% of the mean response determined at 22 °C.

Corrections to instrument readings for air density changes shall be made when appropriate (e.g., for vented ionization chambers).

9.1.2 Test

The instrument shall be exposed in a reproducible geometry in an environmental chamber to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The mean instrument response at 22 °C ± 2 °C shall be determined after a sufficient number of instrument readings are taken in accordance with 4.3. The temperature inside the chamber shall be raised or lowered at a rate not > 10 °C/h until the temperature extremes have been reached. The mean instrument response shall be determined from readings taken at each 10 °C increment. The instrument shall be permitted to come to thermal equilibrium at each temperature level before data are taken.

9.2 Temperature shock

9.2.1 Requirements

An instrument’s response when exposed to a temperature change from 22 C° to –10 C°, –10 C° to 22 C°, 22 C° to 50 C°, and 50 C° to 22 C° in less than 5 min shall be within 20% of the response at 22 °C.

If the instrument does not meet the above requirements, the manufacturer shall state the time required for the instrument to recover to within 20% of the reference reading. The recovery time shall be < 2 h.

This test should be performed on each user-selectable range although susceptibility is typically indicated on the lowest or most sensitive range.

9.2.2 Test

Place the instrument in a controlled environment of 22 °C ± 2 °C and allow it to stabilize for a minimum of 60 min. Expose the instrument to a radiation source of sufficient intensity to minimize the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The mean instrument response shall be determined after a sufficient number of readings are taken in accordance with 4.3.

The instrument and radioactive source shall then be exposed to a temperature of 50 (+0, –5) °C. The temperature change process shall be performed in less than 5 min.

The instrument shall be observed continuously from the temperature change. Every 15 min, the mean instrument response shall be determined from a series of instrument readings. If the instrument remains unacceptable (> 20% difference) after the first hour, readings shall be taken for an additional hour.

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. The instrument shall be observed continuously from the temperature change. Every 15 min, the mean instrument response shall be determined from a series of instrument readings. If the instrument remains unacceptable (> 20% difference) after the first hour, readings shall be taken for an additional hour.

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.

Repeat this process for the 22 °C to –10 (+5, –0) °C and –10 (+5, –0) °C to 22 °C temperature shock.

9.3 Humidity

9.3.1 Requirements

The mean instrument response shall be within 15% of the mean instrument response determined at 40% relative humidity (RH)/22 °C during and after exposure to a noncondensing RH range of 40% to 93% at 30 °C.

9.3.2 Test

The instrument shall be exposed to a radiation source of sufficient intensity to minimize the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The mean instrument response at 40% ± 5% RH and a temperature of 22 °C ± 2 °C shall be determined after a sufficient number of readings are taken in accordance with 4.3, and after a minimum exposure period in this atmosphere of 4 h. The instrument shall be switched off. The RH and temperature shall then be increased to 93% ± 5% and 30 °C ± 2 °C. This environment shall be maintained for 24 h. During the last hour of exposure, the instrument shall be switched on, and after being permitted to stabilize, the mean instrument response shall be determined. The RH and temperature shall be decreased to 40% ± 5% and 22 °C ± 2 °C, and then maintained at that level for a minimum of 4 h. The mean instrument response shall then be determined.

9.4 Mechanical shock

9.4.1 Requirements

The mean instrument response for portable survey meters shall be within 15% of the reference reading after being subjected to 10 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).

9.4.2 Test

The instrument shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The mean instrument response shall be determined after a sufficient number of instrument readings are taken in accordance with 4.3. The instrument shall then be subjected to 10 pulses of peak acceleration of 50 g (half sine-wave pulse), each over a nominal time interval of 18 ms in one of three orthogonal directions. The mean instrument response shall again be determined in the same exposure geometry as used initially. The instrument shall be subjected to similar sets of shock pulses in the other two orthogonal directions and the mean instrument response determined after each shock in the same exposure geometry. The instrument shall be inspected and the physical condition documented.

9.5 Vibration

9.5.1 Requirements

The mean instrument response shall be within 15% of the pretest response following exposure to vibrations of 2 g applied for 15 min in the frequency range of 10 Hz to 33 Hz. The physical condition of the instrument shall not be affected by this vibration (e.g., solder joints shall hold, nuts and bolts shall not come loose).

9.5.2 Test

The instrument shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The mean instrument reading shall be determined after a sufficient number of instrument readings are taken in accordance with 4.3. The instrument shall then be subjected to vibrations of 2 g for 15 min in each of three orthogonal directions at a minimum of one frequency in each of the following ranges: 10 Hz to 21 Hz and 22 Hz to 33 Hz. After each 15 min vibration interval, the mean instrument response shall be determined in the same exposure geometry as used initially and compared to the pretest response. The instrument shall be inspected and the physical condition documented.

9.6 Ambient pressure

9.6.1 Requirements

The mean instrument response shall be within 15% of the mean instrument response at an ambient pressure of 101 kPa over the ambient pressure range of 70 kPa to 106 kPa. Corrections to instrument readings for air density changes are to be made when appropriate (e.g., for vented ionization chambers).

This requirement does not apply to gas or air proportional instruments.

9.6.2 Test

The instrument shall be exposed in a reproducible geometry to an acceptable source of ionizing radiation of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument readings and to produce a response of approximately mid-scale or mid-decade. The mean instrument response at 101 kPa shall be determined after a sufficient number of instrument readings are taken in accordance with 4.3. The ambient pressure shall be changed at a rate ≤ 20 kPa/min. Data shall then be obtained at 106, 92, 84, 76, and 70 kPa. The instrument and temperature shall be permitted to stabilize at each pressure before data are taken.

10. Documentation

10.1 Operation and maintenance manual

Each instrument should be supplied with an appropriate manual in accordance with IEC 61187-1993.

10.2 Type test report

The manufacturer shall make available on request a report including results of the tests performed to determine compliance with the requirements of this standard. The report shall include the manufacturer's name and address, type of instrument, detector(s), serial numbers used in the test, and the date of tests.

Annex A

(informative)

Bibliography

For further information, see the references listed in Clause 2.

[B1] ANSI N323A-1997, American National Standard Radiation Protection Instrumentation Test and Calibration.[11]

[B2] IEC 60068, Basic Environmental Testing Procedures.[12]

[B3] IEC 60846-1989, Beta, X and gamma radiation dose equivalent and dose equivalent rate meters for use in radiation protection.

[B4] IEC 60532-1992, Radiation protection instrumentation—Installed dose ratemeters, warning assemblies and monitors—X and gamma radiation of energy between 50 keV and 7 MeV.

[B5] NBS Special Publication 250-1989, Calibration Services User's Guide.[13]

[11]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[12]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, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA.

[13]NBS 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/).

Annex B

(informative)

Tests performed with variation of influence quantities

Table B.1—Tests performed with variation of influence quantities

Characteristics under test (influence quantity)	Clause	Requirements	Method of test
General characteristics			
Battery power	5.11	5.11.1	5.11.2
Battery power indicator	5.12	5.12.1	5.12.2
AC-powered instruments with battery backup	5.13	5.13.1	5.13.2
Electronic and mechanical tests			
Check circuits	6.1	6.1.1	6.1.2
Alarms	6.2	6.2.1	6.2.2
Stability	6.3	6.3.1	6.3.2
Geotropism	6.4	6.4.1	6.4.2
Response time	6.5	6.5.1	6.5.2
Coefficient of variation	6.6	6.6.1	6.6.2
Line noise	6.7	6.7.1	6.7.2
Electrostatic discharge	6.8	6.8.1	6.8.2
Radiation response			
Accuracy	7.1	7.1.2	7.1.2.1, 7.1.2.2, 7.1.2.3
Probe surface sensitivity	7.2	7.2.1	7.2.2
Photon energy dependence	7.3	7.3.1	7.3.2
Beta energy dependence	7.4	7.4.1	7.4.2
Neutron energy dependence	7.5	7.5.1	7.5.2
Overload	7.6	7.6.1	7.6.2
Angular dependence	7.7	7.7.1	7.7.2
Interfering response			
Extracameral response	8.1	8.1.1	8.1.2
RF fields	8.2	8.2.1	8.2.2

Table B.1—Tests performed with variation of influence quantities *(continued)*

Characteristics under test (influence quantity)	Clause	Requirements	Method of test
Conducted immunity	8.3	8.3.1	8.3.2
Magnetic fields	8.4	8.4.1	8.4.2
Interfering ionizing radiation	8.5	8.5.1	8.5.2
Environmental factors			
Temperature	9.1	9.1.1	9.1.2
Temperature shock	9.2	9.2.1	9.2.2
Humidity	9.3	9.3.1	9.3.2
Mechanical shock	9.4	9.4.1	9.4.2
Vibration	9.5	9.5.1	9.5.2
Ambient pressure	9.6	9.6.1	9.6.2