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American National Standard for Radiation Protection Instrumentation Test and Calibration, Portable Survey Instrumentation for Near Background Operation

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

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American National Standard for Radiation Protection Instrumentation Test and Calibration, Portable Survey Instrumentation for Near Background Operation

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American National Standards Institute

Secretariat

The Institute of Electrical and Electronics Engineers, Inc.

Approved 30 September 2003

American National Standards Institute

Abstract: Minimum performance requirements for portable radiation protection instruments used for detection and measurement of ionizing radiation fields or levels of radioactive surface contamination that are near background levels are established in this standard.
Keywords: instrumentation, near background, portable survey, radiation

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Introduction

(This introduction is not part of ANSI N323B-2003, American National Standard for Radiation Protection Instrumentation Test and Calibration, Portable Survey Instrumentation for Near Background Operation.)

This standard is the responsibility of the Accredited American Standards Committee on Radiation Instrumentation, N42. Committee N42 delegated development of this standard to Subcommittee N42.RPI. Drafts were reviewed by Committee N42, Subcommittee N42.RPI, and other interested parties, and the comments received were utilized in producing the standard as finally approved. The standard was approved on N42 letter ballot of 8 November 2001.

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American National Standard for Radiation Protection Instrumentation Test and Calibration, Portable Survey Instrumentation for Near Background Operation

1. Scope

This standard establishes minimum acceptance performance requirements for portable radiation protection instruments used for detection and measurement of ionizing radiation fields or levels of radioactive surface contamination that are near background.

For purposes of this standard, portable radiation protection instruments are those battery-powered instruments that are carried to a specific facility or location for use.

Specifically, this standard is intended to apply to those instruments utilized to make in-situ measurements for confirmation of residual radioactivity levels that are below criteria established to permit the unrestricted release of a surface area or component from further regulatory controls.

This standard is intended to define performance requirements and acceptance testing that supplements those established in ANSI N42.17A-1989 [B7] and ANSI N42.17C-1989 [B8], and to define calibration requirements that supplement those established in ANSI N323A-1998 [B6].[1] This standard is applicable to the measurement of gamma, beta, and alpha radiation emissions only. This standard addresses the instrument response requirements for the same range of surface activity covered by the above ANSI standards, but extends the applicable range of dose-rate response below those standards. This is illustrated in Table 1.

Throughout this standard, three verbs have been used to indicate the degree of rigor intended for each specific test or performance 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.

[1]The numbers in brackets correspond to those of the bibliography in Annex B.

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Table 1—Extension of requirements of ANSI N42.17A-1989 and ANSI N323A-1998 to ANSI N323B-2003 (this standard)

Standard	Dose rate	Surface activity
ANSI N42.17A-1989 [B7] ANSI N42.17C-1989 [B8]	1 μGy/hr – 10 Gy/hr (0.1 mrad/hr – 1000 rad/hr) 1 μSv/hr – 10 Sv/hr (0.1 mrem/hr – 1000 mrem/hr)	0.02 Bq/cm^2 – 167 Bq/cm^2 (120 dpm/100 cm^2 – 10^6 dpm/100 cm^2)
ANSI N323A-1998 [B6]	1 μGy/hr – 10 Gy/hr (1 mrad/hr – 1000 rad/hr) 1 μSv/hr – 10 Sv/hr (1 mrem/hr – 1000 rem/hr)	0.02 Bq/cm^2 – 200 Bq/cm^2 (120 dpm/100 cm^2 – 1.2×10^6 dpm/100 cm^2)
ANSI N323B-2003 (this standard)	0.1 μGy/hr – 100 μGy/hr (10 μrad/hr – 10 mrad/hr) 0.1 μSv/hr – 100 μSv/hr (10 μrem/hr – 10 mrem/hr)	0.02 Bq/cm^2 – 167 Bq/cm^2 (120 dpm/100 cm^2 – 1.2×10^6 dpm/100 cm^2)

2. Definitions

2.1 absorbed dose: The mean energy deposited per unit mass of the specified absorbing medium.

2.2 acceptable source: The source of radiation listed in the appropriate reference source table in this standard.

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

2.4 accredited testing and/or calibration laboratory: A testing and/or calibration laboratory that has been accredited by an authoritative body with respect to its qualifications to perform verification and/or calibration tests on the types of instruments covered by this standard.

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

2.6 adjust: To alter the response by means of a variable built-in control such as a potentiometer or software.

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

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

2.9 check source: A radioactive source, not necessarily calibrated, that is used to confirm the continuing satisfactory operation of an instrument. *See*: **source response check.**

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

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2.11 contamination monitor: An assembly, including one or several radiation detectors and associated assemblies, designed to measure activity (alpha, beta, photon, or alpha-beta) per unit surface area or activity of a localized source associated with the contamination of the examined object.

2.12 conventionally true value (CTV) of a quantity: The commonly accepted best estimate of the value of a quantity. This and the associated uncertainty will preferably be determined by a national or transfer standard, 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), formerly the U. S. Bureau of Standards and Technology, or a qualified secondary laboratory.

2.13 correction factor: The factor by which the reading of an instrument is multiplied to obtain the conventionally true value of the quantity.

2.14 counting efficiency: The ratio, expressed as a percentage, of the instrument net reading to the surface emission rate of a source under given geometrical conditions.

2.15 decade: A range of values for which the upper value is a factor of ten larger than the lower value.

2.16 decision threshold: A measurement value which allows a decision to be made for each measurement with a given probability of error as to whether the measurement includes a contribution from a radiation source above that contained in background.

NOTE—See Type 1 error, ISO 11929-1:2000 [B17].

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

2.18 detection limit: The extreme of detection or quantification for the radiation of interest. It is the minimum statistically quantifiable instrument response or reading. The upper measurement level is the maximum level at which the instrument meets the required accuracy.

NOTE—See Type 1 error, ISO 11929-1:2000 [B17].

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

2.20 dose: A generic term including absorbed dose and/or dose equivalent. *See also*: **absorbed dose; dose equivalent**.

2.21 dose equivalent (H): The product of D and Q at the point of interest in tissue, where D is the absorbed dose and Q is the quality factor.

2.22 drift: A change in reading, usually gradual, without concomitant change in the influence quantity.

2.23 effective center: The point within a detector where the response, for a given set of irradiation conditions, is the same as that produced if the entire detector were located at that point.

2.24 effective energy: The energy used to characterize a heterogeneous radiation field that behaves under specified conditions as if it were a mono-energetic radiation field of the same energy.

2.25 energy dependence: The variation in instrument response as a function of radiation energy for a constant radiation type and absorbed dose-rate reference to tissue or air.

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

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2.27 functional check: A check (often qualitative) to determine that an instrument is operational and capable of performing its intended function. Such checks may include, for example, battery check, zero setting, or source response check.

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

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

2.30 influence quantity: A radiation field, electromechanical condition, or environmental condition that may produce a response.

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

2.32 laboratory certified instrument: An instrument or specific type of instrument that has been certified by a third-party accredited testing laboratory as meeting the requirements of this standard.

2.33 manufacturer certified instrument: An instrument that has been certified and warranted by the manufacturer as meeting the requirements of this standard.

2.34 national standard: An instrument, source, or other system or device maintained and promulgated by NIST.

2.35 performance check: An evaluation of the performance of an instrument in response to a given influence quantity. *See*: **source response check**.

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

2.37 precision: *See*: **reproducibility**.

2.38 range: All values lying between the detection limit and the upper measurement level.

2.39 reading: The indicated value of the readout.

2.40 readout: The portion of the instrument that provides a visual display of the instrument response.

2.41 reference orientation: The orientation in which the instrument is normally intended to be operated, as stated by the manufacturer.

2.42 reference point: A mark (or markings) on the outside of an instrument, used to determine the effective center of the sensitive volume at which the conventionally true absorbed dose rates are known.

2.43 reference radiation: The radiation selected for calibration of the instrument using sources relatable to national or international standards.

2.44 reproducibility (precision): The degree of agreement between repeated measurements of the same quantity, expressed quantitatively as the standard deviation computed from the results of the series of measurements.

2.45 response: The instrument reading produced as a result of some influence quantity. For purposes of calibration, response is the quotient of the instrument reading divided by the true value of the quantity being measured.

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NOTE—See NCRP Report No. 112 [B19].

2.46 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.

2.47 secondary standard: An instrument, source, or other system or device that has been compared directly with the national standard. *See also*: **national standard**.

2.48 sensitivity: The ratio of the variation of the observed quantity to the corresponding variation of the measured quantity, for a given value of the measured quantity.

2.49 source response check: The check of instrument response to a source to determine that the instrument is still functional within an acceptable range.

2.50 tertiary standard: An instrument, source, or other system or device that has been compared directly with a secondary standard. Generally reserved for use as a laboratory standard. *See also*: **secondary standard**.

2.51 transfer standard: A physical measurement standard, specifically designed for transport, 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. *See also*: **national standard**.

2.52 type test: An initial test of one or more production instruments made to a specific design to show that the design meets certain specifications.

2.53 uncertainty: The estimated bounds of the deviation from the conventionally true value, generally expressed as a percent of the mean, and ordinarily taken as the square root of the sum of the squares of the two components: a) Those components that are evaluated by statistical means; and b) those components that are evaluated by other means.

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

2.55 working standard: An instrument, source, or other system or device calibrated by comparison to a standard other than the national standard. *Contrast*: **national standard**.

3. General requirements

The requirements for measuring and assessing ionizing radiation fields or levels of radioactive surface contamination that are near background are associated with release of materials from radiological control for recycling, reuse, or disposal; and of surfaces or areas remaining at the completion of decontamination and/or decommissioning activities. Criteria for these release activities are established by various regulatory authorities including the Nuclear Regulatory Commission (NRC) NRC Regulatory Guide 1.86-1974 [B21]; 10 CFR Part 20 [B2]; NUREG-1640-2003 [B22], the Environmental Protection Agency (EPA) 40 CFR 192 [B3], and the Department of Energy (DOE) 10 CFR 835 [B1]. These release criteria near levels that are equivalent to the natural radioactive background require adequate factors for assessing radiological measurements to determine if a residual level of radioactivity remains requiring further consideration of the item of interest or if that item may be released from further regulatory control.

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3.1 The calibration process

The calibration process begins with the operational characteristics defined for an instrument to meet selected performance requirements. These operational characteristics, as defined by a series of type tests, indicate how accurately the instrument is expected to respond to a radiation environment under variable operational conditions. ANSI N42.17A-1989 [B7] and ANSI N42.17C-1989 [B8] set forth performance criteria and test methods for portable instruments. ANSI N42.17A-1989 [B7] should be used as a guide in establishing the operational requirements for all instruments used at a specific facility or site. This standard shall focus on instrument calibration requirements subsequent to receipt of the instrument by the owner/user having confirmation that the instrument was successfully type tested prior to receipt. Figure 1 provides a diagram illustrating various user activities associated with field use calibration. The primary user activities include the following:

— Instrument receipt inspection and acceptance testing
— Initial instrument calibration and issue for use
— Field receipt
— Daily field calibration verification and functional checks
— Recalibration (scheduled verses unscheduled)

3.2 Initial acceptance testing

An acceptance test should consist of

a) A physical inspection
b) A general operations test
c) Source tests

and should precede the initial instrument calibration. The physical inspections and general operations tests should be performed on each instrument. The source tests should be performed on a random selection of 10% of the instrument batch or four instruments, whichever is larger. If one instrument in a sample of a large quantity fails the test, an additional 10% should be tested. An additional failure would result in the need to test the entire batch.

3.2.1 Physical inspection

A physical inspection is an inspection identifying any physical abnormalities that may affect instrument operations (e.g., inspecting instruments for broken parts, loose or missing screws, loose or misaligned knobs, calibration potentiometers not aligned with access holes, circuit boards not secured, loose wires, loose connectors, and loose components; testing moving parts; or ensuring that batteries are fresh and properly installed).

3.2.2 General operations test

A general operations test is a determination of nonradiological operating functions (e.g., checking battery condition, verifying the mechanical zero, testing the meter zero potentiometer, checking for switching transients, or checking for zero drift on the meter or light sensitivity, if applicable).

3.2.3 Source tests

Source tests are determinations of radiological operating functions (e.g., checking source response, geotropism, variability of readings, stability, temperature response, humidity response, or photon energy response). Temperature, humidity, and energy-response tests may consist of single data points at extremes of these variables to test against specifications.

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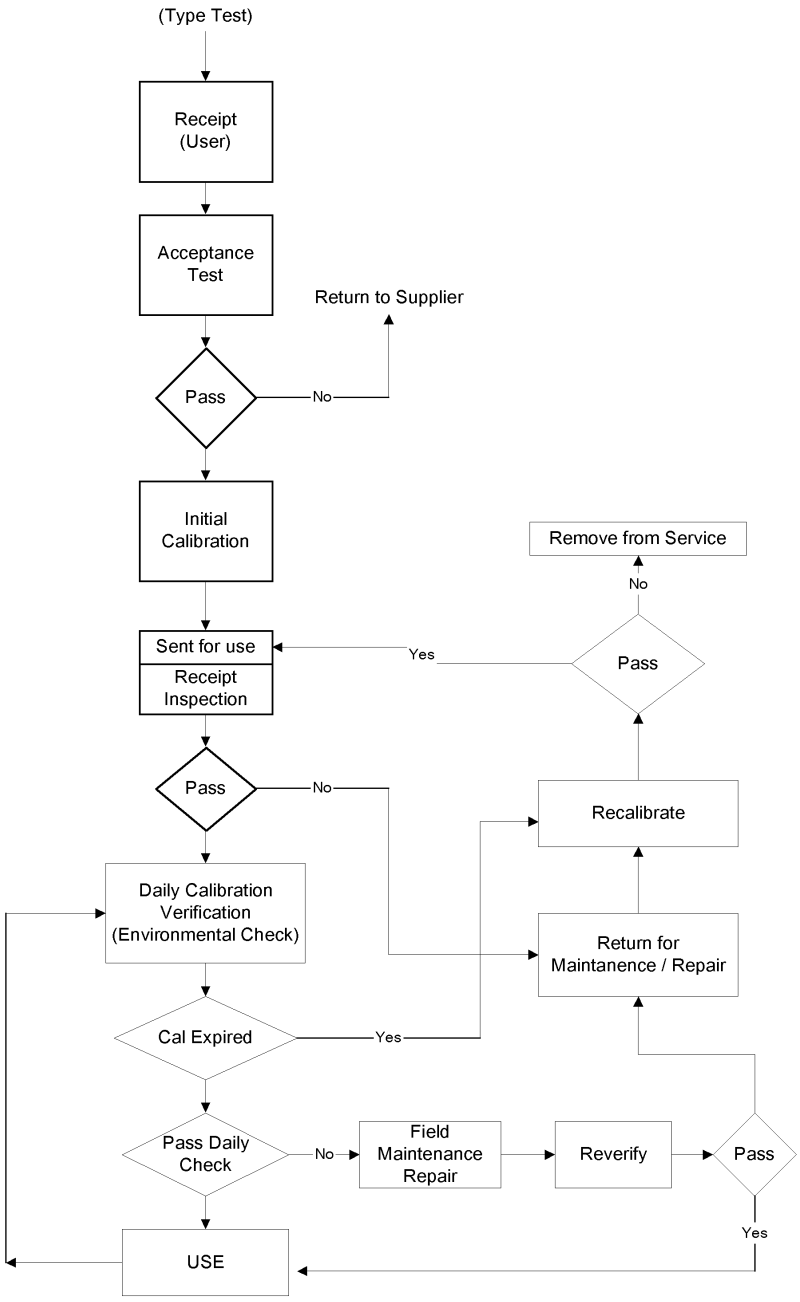


Figure 1—Calibration activities for field use supplier

3.3 Instrument calibration

Calibration is a set of operations that establish, under specified conditions, the relationship between values indicated by an instrument and the corresponding known (i.e., conventionally true) values of the quantity to be measured.

Calibration shall include adjustment and/or determination of new readings for each point selected on the scale. Electronic calibration may be acceptable for some instrument ranges where calibration with a source is impractical, provided the electronic calibration is related to actual exposure data at one or more points.

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Electronic calibration may be insufficient for assessing instrument response to radiation environments that are less than 1 μGy/hr (100 μrad/hr). This issue is most pronounced for gamma count rate and gamma dose-rate instruments. For determining a calibration factor in this range either a conventionally true value for a gamma dose-rate field must be established or a secondary standard employed. The following conditions shall be established prior to exposing the instruments to a source for adjustment and calibration:

a) The meter shall be adjusted to zero or the point specified by the manufacturer.
b) The batteries or power supply shall comply with the instrument manufacturer's specification.
c) The instrument shall be turned on and allowed to stabilize as appropriate.
d) Electronic adjustments such as high voltage shall be set either to the site specifications or to the manufacturer's specifications, as applicable.
e) The effect of geotropism shall be known for the instrument, and this effect shall be taken into account during calibration.

The specific calibration requirements for various instruments are given in Clause 6.

3.4 Field use

When calibration is complete and the instrument is assigned for field use, a program of continuing calibration verification shall be established. This verification shall consist of

— Field receipt inspection
— Daily verification performance testing

3.4.1 Receipt inspection

Prior to using an instrument to perform field measurements, that instrument shall be inspected to verify that operability and response are consistent with conditions on which the calibration was determined. A receipt inspection shall include those activities described in 3.2 that include a physical inspection, general operations testing, and a source check. Measured parameters shall be compared to the values recorded on the calibration data sheets (see Clause 4 and Clause 5) that accompany the instrument. If any of these parameters exceed the calibration values by ±10%, the instrument should be returned for maintenance and/or recalibration.

3.4.2 Daily verification

Daily, before use, each instrument shall be checked for proper response. Physical inspection and general operations testing shall be based on the same parameters and/or conditions that were verified during receipt inspection. Daily source checks may be performed using the original calibration standard, if available for field use, or a check source that verifies consistent response. The same source-detector geometry routine shall be used when performing daily source response checks. An instrument's response to ambient background radiation may be used instead of check source provided that

— The instrument's application primarily involves a point of interest that is near the level of ambient background radiation;
— The instrument's response to ambient background radiation is characterized and documented;
— The instrument's response to background radiation is routinely monitored; and
— Provisions are made for removing the instrument from service in the event the instruments response to ambient background radiation changes by an amount that cannot be attributed to expected changes in the background level.

Daily source checks should be documented using control charts that include the range of acceptable operation.

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3.5 Recalibration

Recalibration of an instrument may be determined by either a predefined frequency interval or by the instrument's failure to pass more than once the daily performance requirements. Recalibration activities include

— Pre-calibration inspection
— Maintenance as required
— Recalibration

3.5.1 Pre-calibration

Pre-calibration shall include a visual examination of the instrument condition and a documentation of the instrument response, upon return from the field, by obtaining "as found" readings for one calibration point on each scale. "As found" readings shall be taken prior to any adjustments on the instrument, unless the instrument is returned in an inoperable condition. Pre-calibration should include verification that radioactive contamination on the instrument is low. It should be less than the NRC Regulatory Guide 1.86-1974 [B21] and 10 CFR 835 [B1] guidelines. If contamination exceeds these guidelines, the instrument should be decontaminated prior to further calibration activity. If decontamination is not possible or economically unjustified, the instrument shall be handled and disposed of as radwaste.

3.5.2 Instrument maintenance

Instrument maintenance shall be performed using components that are at least equivalent to those specified by the manufacturer. If the manufacturer does not provide maintenance instructions, maintenance instructions should be written and approved by persons in the organization responsible for performing the maintenance and/or calibration. The instructions should include requirements for training and qualification of workers, for specifying the quality of replacement components, and for control of workmanship quality. When the manufacturer does provide written instructions, the organization responsible for maintenance and/or calibration may document acceptance of the instructions.

Repairs made using unapproved instructions or components that may affect instrument performance constitute an instrument modification and shall be considered to render invalid any type tests made on the instrument model as applied to the specific instrument. Modified instruments shall have their performance tested and documented prior to issuance for field use. If the user can document that the modification will not affect the performance of the instrument, additional testing shall not be required.

3.5.3 Recalibration

At the completion of pre-calibration and any required maintenance activities, the instrument shall be recalibrated using the protocols defined for the initial calibration discussed in 3.3.

3.6 Calibration frequency

The calibration shall be performed at a frequency required to maintain an acceptable accuracy for the intended measurement application, but in no case shall the frequency exceed one year (ANSI 323A-1997 [B6]; USDOE [B25]). Where instruments are subjected to extreme operational conditions, hard usage, multishift use, or corrosive environments, more frequent primary calibration should be scheduled. If greater than 10% of the as-found responses of the instruments are out of the calibration acceptance range, consideration should be given to increasing the calibration frequency.

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4. Performance requirements

4.1 General

Periodically, over the life of the instrument, all instruments should be performance tested to verify that they continue to meet the operational requirements. Testing and calibration of instruments should be performed under a group of controlled conditions called standard test conditions, see Table 2. This recommendation is intended to ensure that the performance characteristics relate to the calibrated instrument.

Table 2—Standard conditions

Influence quantities	Acceptable range for standard test conditions
Warm-up time	> 1 min or manufacturer's specifications
Relative humidity	Ambient ±10%, not to exceed 75%
Ambient temperature	20 °C – 24 °C
Atmospheric pressure	70 – 106 kPa
Background ambient photon radiation (external)	< 10% of full scale of the range or decade under test, but nominally should not exceed 0.1 µGy/hr (10 µR/hr) referenced to air
Non-ionizing electromagnetic field of external origin	Less than 50% of 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 for normal operation per site procedure or manufacturer's recommendations
Contamination by radionuclides	Contamination shall be low and should be less than limits for total activity listed in NRC Regulatory Guide 1.86-1974 [B21], 10 CFR 835 [B1], or ANSI N13.12-1999 [B5].
Reference point	Effective center[a]

[a]For larger area beta or alpha detectors, the detector source response factor should be based on contact with the detector "face."

4.1.1 Normal-use calibration

Recalibration, maintenance, performance tests, and functional tests shall be conducted periodically to ensure that the instruments continue to meet the performance requirements for field measurements. Periodic recalibration is distinct from a field test or a simple evaluation with a check source. It includes a pre-calibration check followed by adjustment and calibration, as described in 3.5.

Performance tests, as discussed in 4.2, shall be repeated routinely because aging or replacement of components may affect the performance of the instrument. The performance tests that should be performed periodically (at least annually), or performed after maintenance that could affect performance are: range, sensitivity, linearity, detection limit, and response to overload conditions. These tests may be conducted, as part of the calibration procedure. If maintenance could affect instrument performance (i.e., energy response, temperature response, etc.), performance tests shall be conducted to evaluate the response characteristic that may have been impacted. Any changes in the performance characteristics of the instrument shall be documented, and the documentation shall be provided to the user.

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4.1.2 Special-use conditions

If the instrument to be used for conditions other than those for which it was performance tested (e.g., used outside the designed energy range or under different environmental conditions), calibration or performance testing for these conditions shall be performed. Similarly, if the instrument is physically altered such that the previous calibration and performance tests could be invalidated, calibration and retesting shall be performed. It should be noted that where calibration or performance tests are performed under several variables (such as temperature, dose rate, and humidity), only one variable shall be changed while other conditions shall be held constant.

Components may change values with time or even fail. A functional check shall be made by the user daily or prior to use to ensure that the instrument is operating properly (see 3.4).

4.2 Electronic and mechanical effects

Performance testing that assesses the effects of the electronic and mechanical characteristics of an instrument is described in ANSI N42.17A-1989 [B7], Clause 5. The characteristics discussed in that standard that are directly applicable to portable instruments used to measure near-background radiation conditions include the following:

— Battery power
— Circuit checks
— Electronic stability
— Geotropism
— Response time
— Coefficient of variation

The performance requirements for instruments covered by this standard are discussed in the following sections. The testing protocols to verify those requirements shall follow the requirements in ANSI N42.17A-1989 [B7]. The limits of variation on these performance characterizations are based on values from ANSI N42.17A-1989 [B7] and modified as applicable to the scope of this standard. These are summarized in Table A.1.

4.2.1 Battery power

Instruments with a self-contained, nonrechargeable power supply should operate with continuous battery lifetime of at least 100 hr using readily available batteries. Battery lifetime and operating temperature ranges for continuous operation and normal storage under all conditions shall be stated by the instrument manufacturer. Instruments that use rechargeable batteries shall operate for a minimum of 8 hr with a maximum recharging time of 16 hr. The manufacturer shall state the minimum voltage required to produce satisfactory operation of the instrument where satisfactory operation is defined as less than 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 for satisfactory operation as defined above.

4.2.2 Check circuits

Checks of the audit and test circuits and audio indicators, automatic or manual, should be performed. Perform testing per manufacturer’s specifications to determine compliance.

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4.2.3 Electronic stability

The mean instrument response at constant temperature and pressure shall vary not more than 6% from the mean of a set of reference readings over a period of 3 hr for survey meters after a warm-up period specified by the instrument manufacturer but not to exceed 15 min.

4.2.4 Geotropism

A change in the mean instrument reading caused solely by change in spatial orientation of survey meters shall be not greater than 6% of the mean of a set of readings obtained with the instrument in the reference orientation.

4.2.5 Response time

Instrument response time for increasing exposure rates for beta-photon dose-rate readouts shall be in accordance with Table 3. Instruments suitable for both neutron and photon or neutron, beta, and photon shall meet the least restrictive value specified in Table 3.

Table 3—Instrument response time vs. scale or decade maximum for increasing exposure rates

Scale or decade maximum		Maximum response time (s)
(μGy/hr)	(μrad/hr)	
> 0.1 to ≤ 1.0	> 10 to ≤ 100	30
> 1.0 to ≤ 10	> 100 to ≤ 1,000	30
> 10 to ≤ 100	> 1 mrad/hr to ≤ 10 mrad/hr	10

Instrument response time for count rate readout (i.e., contamination monitors) should be less than 30 s for gas-flow units and less than 10 s for other type units (e.g., air proportional, scintillation). Instruments with variable response times shall be tested on the fastest response time available for each scale or decade.

Response time with respect to increasing and decreasing exposure rates shall be stated by the manufacturer.

4.2.6 Coefficient of variation

The coefficient of variation of 20 instrument readings from a single instrument shall not be more than Table 4 values for portable exposure and dose-rate instruments, and for portable contamination monitors exposed to radiation intensities as stated in the table.

4.3 Radiation response

Performance testing that assesses the response of the instrument to various radiation effects are discussed in ANSI N42.17A-1989 [B7], Clause 6. For portable instruments intended for measuring radiation conditions near natural background levels, the radiation effects that shall be defined include

— Accuracy
— Photon energy dependence
— Beta energy dependence
— Angular dependence

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Table 4—Allowable instrument coefficient of variation vs. scale or decade maximum

Exposure/dose rate	Surface activity	Coefficient of variation
> 0.1 to ≤ 1.0 µGy/hr (> 10 to ≤ 100 µrad/hr)	< 3.3 Bq (< 200 dpm)	30%[a]
> 1.0 to ≤ 10 µGy/hr (> 0.1 to ≤ 1.0 mrad/hr)	> 3.3 to ≤ 33 Bq (> 200 to ≤ 2000 dpm)	15%
> 10 to ≤ 100 µGy/hr (> 0.1 to ≤ 10 mrad/hr)	> 33 Bq (> 2000 dpm)	10%

[a]Except for alpha instruments counting background using a one-minute counting interval. COV = 50%

The limits of variation for instrument response to these conditions are based on values from ANSI N42.17A-1989 [B7] and modified as applicable to the scope of this standard. Testing protocols to verify these requirements shall follow ANSI N42.17A-1989 [B7], as applicable.

4.3.1 Accuracy

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):

$$0.90 \leq \frac{r_i}{CTV_{ref}} \leq 1.10 \quad (1)$$

where

r_i = the mean indicated value,
CTV_{ref} = the conventionally true value of the reference radiation.

4.3.2 Photon energy dependence

The useful energy range for photon measuring instruments shall be stated and graphically indicated and shall be the continuous interval of photon energies over which the following condition is met, as shown in Equation (2):

$$0.8 \leq \left(\frac{r_{eni}/CTV_{eni}}{r_{ref}/CTV_{ref}}\right) \leq 1.2 \quad (2)$$

where

r_{eni} = the mean indicated reading to photon radiation of energy i,
r_{ref} = the mean indicated reading to the reference photon radiation,
CTV_{eni} = the conventionally true value of the photon radiation of i,
CTV_{ref} = the conventionally true value of the reference photon radiation.

The useful energy range should be at least 20 keV to 3 MeV and shall be at least 80 keV to 1.33 MeV. It shall be stated by the manufacturer. The manufacturer shall also state the energy used as a reference point. For instruments designed for energies outside this range, the useful energy interval shall be stated by the manufacturer, and the instrument shall be clearly marked that it is to be used for this restricted application only.

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The range of photon energies over which the instrument response is within 0.5 – 1.5 times the conventionally true value shall be stated or graphically indicated.

4.3.3 Beta energy dependence

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):

$$0.5 \leq \frac{r_{\beta i} / CTV_{\beta i}}{r_{\beta \mathrm{ref}} / CTV_{\beta \mathrm{ref}}} \leq 1.5 \qquad (3)$$

where

$r_{\beta i}$ = the mean indicated reading to beta radiation of energy i,
$r_{\beta \mathrm{ref}}$ = the mean indicated reading to the reference beta radiation,
$CTV_{\beta i}$ = the conventionally true value of the beta radiation of energy i (absorbed dose rate at 7 mg/cm^2 depth in tissue),
$CTV_{\beta \mathrm{ref}}$ = the conventionally true value of the reference beta radiation (absorbed dose rate at 7 mg/cm^2 depth in tissue).

The reference energy source shall be specified by the instrument manufacturer. The beta cutoff energy shall be stated, along with the density thickness (e.g., mg/cm^2) of the material through which the beta radiation must pass to reach the sensitive volume of the detector.

4.3.4 Angular dependence

The mean response of an instrument to a photon radiation incident at any angle not exceeding 45° from the direction of maximum response of the instrument shall be not less than 80% of this maximum response. At an angle of 90° 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 equal to or less than 45° from the direction of maximum response of the instrument should be not less than 50% of this maximum response. The angular response of the detector or instrument, as appropriate, shall be provided as a polar coordinate plot. 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.

4.4 Interfering response

4.4.1 Extracameral response

Extracameral response for photon or beta-photon dose-rate instruments and instruments that have an external detector that can be considered separate from the rest of the unit shall be not greater than 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 ≤ 10 mGy/hr (1 rad/hr) (i.e., instrument response shall be not greater than 5% of the mean-background reading).

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4.4.2 Radio-frequency (RF) fields

The mean instrument response for each detector, obtained when the instrument is exposed to an RF field that is ≤ 100 V/m in intensity in the frequency range of 0.3 MHz to 35 MHz or at a nominal 140 MHz or both,[2] shall vary not more than 50% from the mean instrument response obtained with no RF field present. Alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not properly operate in such fields. Special requirements for other frequencies may be determined by the instrument manufacturer and user.

4.4.3 Microwave fields

The mean instrument response, obtained when the instrument is exposed to a microwave field that is ≤ 100 W/m^2 in intensity at 915 MHz to 2450 MHz, shall vary not more than 15% from the mean instrument response obtained with no microwave field present. Alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not properly operate in such fields.

4.4.4 Electric fields

The mean instrument response, obtained when the instrument is exposed to an electrostatic field that is ≤ 5000 V/m in intensity or to 60 Hz and 400 Hz fields that are ≤ 100 V/m in intensity, shall vary not more than 15% from the mean instrument response obtained with no electric field present. Alternatively, the manufacturer shall specify in the documentation that the instrument may be sensitive to and not properly operate in such fields.

4.4.5 Magnetic fields

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

4.4.6 Interfering ionizing radiations requirements

Instruments designed to measure one or more types of ionizing radiations shall not exhibit a response greater than that stated by the instrument manufacturer to other types of ionizing radiations at or below the levels shown in Table 5.

4.5 Environmental response

4.5.1 Temperature

The temperature range over which the mean instrument response shall not vary by more than 15% from the mean response at a nominal temperature of 22 °C shall be stated by the manufacturer. The mean instrument response shall not vary by more than 15% from the mean response at a nominal 22 °C from 0 °C to 40 °C and shall not vary by more than 20% from the mean response at a nominal 22 °C from –10 °C to 50 °C. Corrections to instrument readings for air density changes shall be made when appropriate (e.g., for vented ionization chambers).

[2]Approximate frequency of most portable transceivers.

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Table 5—Maximum response to interfering ionizing radiation

Response to interfering radiations			
Upper limit of interfering ionizing radiation to which instrument shall be tested			
Radiation(s) measured by instrument	**Alpha** α	**Beta** β[a]	**Photon**[a]
α	—	1 rad/hr	1 rad/hr
$\alpha + \beta$[b]	—	—	1 rad/hr
α + b + photon[b]	—	—	—
β[c,d]	10^4 dpm/cm^2	—	10 rad/hr
β + photon[c,d]	10^4 dpm/cm^2	—	—
β + photon	10^4 dpm/cm^2	—	—
Photon	10^4 dpm/cm^2	10 rad/hr	—

[a]External ambient fields.
[b]Refers to measurement of these in combination; if instrument is claimed to measure one or more types of radiation, any or each singly, then the requirements specified in Table 5 for an instrument measuring only that type of radiation apply.
[c]For thin window (i.e., ≤ 10 mg/cm^2) detectors, interference as specified by the instrument manufacturer from alpha particles is permitted.
[d]For beta-scintillation detectors, interference as specified by the instrument manufacturer from low-energy photons is permitted.

4.5.2 Temperature shock

The mean instrument response shall not vary by more than 15% from a set of reference readings taken at a nominal temperature of 22° C when the instrument is taken from that nominal environment of 22 °C to one of 50 °C or –10 °C in less than 5 min.

The mean instrument response shall not vary by more than 15% from a set of reference readings taken at a temperature of 50 °C or –10 °C when the instrument is taken from either one of those temperatures to one of a nominal 22 °C in less than 5 min.

4.5.3 Humidity

The mean instrument response shall not vary by more than 15% over the noncondensing relative humidity (RH) range of 40 – 95% and a nominal temperature of 22 °C from the mean instrument response at 40% RH and a nominal 22 °C.

4.5.4 Mechanical shock

The mean instrument response for portable survey meters shall not vary by more than 15% from a set of reference readings 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. This requirement applies to survey instruments only. 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).

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4.5.5 Vibration

The mean instrument response shall not vary by more than 15% from a set of reference readings following harmonic loadings of 2 g applied for 15 min in the frequency range of 10 Hz to 33 Hz. The physical condition of instruments shall not be affected by this vibration (e.g., solder joints shall hold, nuts and bolts shall not come loose).

4.5.6 Ambient pressure

The mean instrument response shall not vary by more than 15% from 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 shall be made when appropriate (e.g., for vented ionization chambers). This requirement does not apply to gas or air proportional instruments.

4.5.7 Splash proof

The mean instrument response shall vary not more than 15% from the mean of a set of reference readings after being subjected to water spray in accordance with ANSI 42.17A-1989 [B7], 8.7.2. This requirement does not apply to detectors open to the air, detectors with thin windows, ac-powered units, or ac-powered units with battery backup.

5. Calibration facility requirements

5.1 Calibration standards

Instruments shall be calibrated with appropriate standards that are traceable to NIST or its international equivalents. Working standards derived from secondary or tertiary standards shall be used and shall be compared at least annually against the secondary or tertiary standards. Calibrations of the reference radiation field or source shall be obtained in one of the following ways:

a) By calibration of a user's instrument with a national or secondary source, followed by evaluation of the user's reference source with the same transfer instrument. The transfer instrument shall have a reproducibility within 2% (one standard deviation).
b) By comparison of the radiation field from a user's reference source with the radiation field from a national or secondary standard source in the same geometry, using a "transfer instrument" that has a reproducibility within 2% (one standard deviation).
c) Where no national or secondary standard exists (as in the case of specific energies, unusual sources, or unusual source configuration), by establishment of a standard source or instrument with documented empirical and theoretical output or response characteristics.

NOTE—If no national or secondary standard exists for the specific energy to be measured, interpolation between known energy response values is to be used. Extrapolation outside the range of known energy response should be avoided.

d) Where the calibration range is approaching the natural background level (0.1 – 1.0 μGy/hr) as established by the calibration laboratory, by establishment of a transfer instrument with a national or secondary standard source and performing a direct comparison with the response of the instrument being calibrated.

NOTE—The use of a Reuter-Stokes pressurized ion chamber, or equivalent, to define the "calibration" field for portable μR meter calibration response is an example of this application.

A calibration source or sources should provide a radiation response sufficient to reach the full scale of any instrument to be calibrated. If the source is a radionuclide, the half-life should be long, preferably greater

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than several years, to minimize corrections and uncertainties. Calibration sources should be taken from Table 6 and shall comply with applicable standards. The uncertainty of source calibration shall be no greater than 10% with respect to national or secondary standards for photons and 10% to 20% for alpha and beta particles for source activities < 1.0 μSv/hr or < 10 Bq/cm^2 (< 100 μrad/hr or < 6×10^4 dpm/100 cm^2).

Table 6—Reference sources for calibration

Radiation Type	Reference Source	Reference
Dose rate		
Gamma	^{137}Cs, ^{60}Co, and ^{241}Am	ISO 4037-1:1996 [B10] ISO 4037-2:1997 [B11] ISO 4037-3:1999 [B12] ANSI N42.17A-1989 [B7]
X-ray	M30, H50, H150, H200, H250, H300, M150, and S60	NBS [B18] ANSI N42.17A-1989 [B7]
X-ray (K fluorescence)	16, 24, 34, 43, 58, 78, and 100 keV	ISO 4037-1:1996 [B10] ISO 4037-2:1997 [B11] ISO 4037-3:1999 [B12]
Beta	^{90}Sr-^{90}Y and ^{204}Tl	ISO 6980:1985 [B13] ANSI N42.17A-1989 [B7]
Surface contamination		
Alpha	^{241}Am, ^{230}Th and ^{239}Pu	ISO 8769:1988 [B16] ANSI N42.17A-1989 [B7]
Beta	^{90}Sr- ^{90}Y, ^{14}C, ^{99}Tc, ^{147}Pm, ^{36}Cl, ^{204}Tl, ^{106}Ru-^{106}Rh, U-Nat and U-Dep	ISO 8769:1988 [B16] ANSI N42.17A-1989 [B7]
Tritium	^{3}H	ISO 8769-1988 [B16]

5.2 Calibration assemblies

Instrument calibration assemblies should be mechanically precise to ensure that positioning uncertainties of either instruments or radiation sources do not affect the radiation field values by more than +2% (ANSI N13.6-1972 [B4]). Personnel shielding, remote instrument reading and positioning facilities, automatic source-handling mechanisms, and other mechanical or remote operations are recommended.

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5.3 Maintenance of standards

Calibration standards shall be maintained through an ongoing measurement quality assurance program with NIST or an appropriate secondary laboratory (NIST [B20]; Swinth et al. [B23]). Laboratories may participate in a calibration accreditation program to demonstrate the competence of the calibration laboratory. Accreditation programs are run through the Conference of Radiation Control Program Directors (CRCPD), the Health Physics Society (HPS), and the National Voluntary Laboratory Accreditation Program (NVLAP) (NIST [B20]; Swinth et al. [B23]). Whenever possible, laboratories should derive their calibration standards from national standards maintained by NIST, its international equivalents, or secondary standards maintained by other accredited laboratories. Direct comparison with national or secondary standards shall be undertaken when the measurement quality assurance program indicates that such actions are needed. Quality control procedures shall be in place to ensure that a working relationship is maintained between the working and derived standards at a facility.

5.4 Check sources

Check sources should provide radiation of the same type or types as provided by those sources used in instrument calibration (as described in 5.1). However, check sources that emit radiation different than that used for calibration may be used if

a) The source/instrument geometry is quantifiable and easily reproduced.
b) The instrument response to the different radiation emission is quantifiable and is not critically dependent on instrument adjustment (e.g., the use of a beta source to check instruments sensitive to a photon radiation may be acceptable while the use of a photon source to check an alpha scintillation detector is not acceptable). A reproducible source/detector geometry shall be established and used for all source response checks.

5.5 Calibration source quality

Sources to be used for calibrations shall comply with national/international standards. Calibration fields shall be known with an accuracy compared to secondary or national standards as indicated in Table 7. For dose rates or surface activity greater than Table 7 application, calibration field accuracies shall be required in accordance with Table 3 of ANSI N323A-1997 [B6].

Table 7—Calibration field accuracies[a] and quantities

Radiation type	Accuracy (%)	Quantity
Gamma	10	Deep dose equivalent
X-ray	10	Deep dose equivalent
Beta	20	Shallow dose equivalent
Alpha contamination	10	Activity/unit area
Beta contamination	10	Activity/unit area

[a]Accuracies are for dose rates less than 1.0 μGy/hr or 10 Bq/cm^2 (100 μrad/hr or 6×10^4 dpm/100 cm^2).

Radiation fields used for calibration shall be characterized and documented in terms of quantity and reproducibility. Such considerations as charged particle equilibrium, scattered or unwanted radiations from the

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source, and ambient background radiation should be accounted for during standardization of the calibration assembly. Fields used for dose and dose-rate instrument calibration should be such that a uniform fluence exists throughout the entire volume of the detector.

Instruments may be calibrated in non-uniform fields (e.g., box calibrators) by using a transfer standard, thus transferring the calibration from a uniform irradiation geometry (free-in-air) to the non-uniform geometry. Radiation sources and standard instruments used in calibration are discussed in Table 6 and Table 7. A good review of calibration assemblies (Technical Report Series 133 [B24]), should be consulted by those responsible for the calibration facility and calibration of instruments.

With the exception of a calibration facility where an uncollimated source is used in a large room (i.e., free space), calibration beams shall be collimated so that their size is limited to an area consistent with calibration requirements. Constancy checks shall be performed annually as a minimum for all sources. Machine-generated beams shall employ continuous beam monitors as a working standard for calibration purposes. Continuous beam monitors shall be calibrated at least annually with secondary or tertiary standards.

The energy spectrum for all calibration sources should be known. If absorbers, collimators, or high-scatter geometries are employed, the effect on the calibration accuracy relative to a low-scatter geometry shall be known. When shutters or other source control devices are used, the effect of transit time on dose equivalent shall be known and accounted for as required.

5.6 Calibration facility

5.6.1 Facility design requirements (USDOE [B25])

The effect of external conditions on the internal environment of the calibration laboratory should be considered in selecting the facility site. The laboratory should be sited away from, or otherwise isolated from, sources of mechanical vibration and shock, sources of electrical and electromagnetic interference, and other potential sources of interference with proper calibration of instrumentation. If such potential sources exist, the laboratory should have documentation that demonstrates an absence of adverse effects on calibration accuracy.

The electrical power should be appropriate for the equipment used, suitably stable, and free of switching transients and significant line noise. When necessary, local auxiliary voltage stabilizers, filters, and uninterruptable power supplies should be provided.

5.6.2 Facility operating requirements

When free-in-air geometry is utilized for photon instrument calibration, the distance of scattering objects from the source and from the detector should be at least twice the distance between the detector and the source. When free-in-air geometry is not practical, the distance to scattering objects from the source and from the detector should be sufficient to maintain the required accuracy in Clause 6.

The radiation background at the calibration facility should be low, known, and stable; and shall be accounted for during calibration.

Calibrations should be performed within the limits of standard conditions as noted in Table 2.

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6. Calibration protocol requirements

A calibration source should normally be used to establish the conversion factor used to convert the instrument response to an estimate of in-situ residual radioactivity. The calibration shall be performed such that an in-situ measurement can be accurately converted to the 4π (total) emission rate of the residual surface activity. Factors important to this conversion are discussed in ASTM E1893-1997 [B9]. The calibration sources used for this determination shall, as a minimum, have the following characteristics (ASTM E1893-1997 [B9]):

1) Have the same type of emissions (alpha, beta, or photon) as the residual radioactive material.
2) Have particle or photon energy that is within ±10% of the energy emitted from residual radioactivity. Alternately, calibration may be established from a curve generated from at least three sources with energies that bracket the energy of interest.
3) Have a particle or photon emission rate that is not more than 50 times the applicable standard for unrestricted release.

The calibration source should also have the following characteristics (ASTM E1893-1997 [B9]):

1) Physical and/or chemical composition that produces similar backscatter characteristics as the residual in-situ radioactive material matrix, for example as shown in Table 8.
2) Distribution (geometry) either within or on the surface that is similar to the residual radioactive material matrix.

Table 8—Calibration source/field measurement backscatter relation

In-situ medium	Source mount
Iron/steel	Steel
Concrete	Aluminum
Wood/plaster	Plastic
Soil	Aluminum
NOTE—The effects of backscatter from different surfaces are most pronounced when interpreting field measurements of beta surface activity.	

6.1 Dose and dose-rate measuring instruments

6.1.1 Linear readout instruments

Linear readout instruments with a single calibration control for all scales shall be adjusted either at the point recommended by the manufacturer or at a point within the normal range of use. Instruments with calibration controls for each scale shall be adjusted on each scale.

NOTE—If instruments have ranges that are not calibrated, a limited calibration tag that notes the limits of calibration shall be attached to the instrument. The same principles should be applied to microprocessor-controlled instruments.

After adjustment, the response of the instrument shall be checked near the end points of each scale (approximately 20% and 80% of full scale).

NOTE—For microprocessor-based instruments that have been proven linear through type testing and/or acceptance testing, only one point on each scale or decade is required.

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Instrument readings shall be within ±15% of the CTV for the lower point and ±10% of CTV for the upper point. Readings within ±20% shall be acceptable if a calibration chart or graph is prepared and provided with the instrument.

6.1.2 Logarithmic readout instruments

Logarithmic readout instruments, which commonly have a single readout scale spanning several decades, normally have two or more adjustments. The instrument shall be adjusted for each scale according to the site specifications or the manufacturer's specifications. Alternatively, it shall be permissible to calibrate at points of particular importance to the user if the reasons for the change and the impact on accuracy are documented and justified.

After adjustment, calibration shall be checked at a minimum of one point on each decade. Instrument readings shall have a minimum deviation from the CTV of no more than 10% of the full decade value. If the display is not marked at intervals corresponding to ±10% of the point (i.e., calibration at a mark frequently does not have graduations to 10% in the next decade), it is permissible to use the spacing on the low side of the calibration point to estimate the calibration limit on the high side of the calibration point.

6.1.3 Digital readout instruments

Digital instruments shall be calibrated as in 6.1.1.

NOTE—For microprocessor-based instruments that have been proven linear through type testing and/or acceptance testing, only one point on each scale or decade is required.

If the instrument is designed to auto scale, the calibration point should be selected far enough from the auto scaling point that auto scaling will not affect the reading. Instruments should be cycled through a complete test of all display segments or indicators, either electronically or radiologically.

6.1.4 Integrating instruments

Instruments that integrate dose shall be checked at a minimum of two dose rates at approximately 20% and 80% of the stated dose-rate range or as recommended by the manufacturer.

NOTE—If the full instrument dose-rate range is not intended for use, then the range acceptable for use shall be noted on the instrument.

The integration shall continue to a value sufficient to ensure a statistically valid reading that shall be within 15% of the CTV. For digital instrumentation, integration should be checked to the maximum reading obtainable on the display. If it is not practical to accomplish the full-scale radiological integration, the electronics and display may be checked electronically at the maximum integration point, with the radiological integration being performed at a lower point that is achievable.

6.1.5 Beta dose measuring instruments

Correction factors for beta dose/dose-rate measurements shall be determined using either ISO 6980:1996 [B13] sources for point sources and standard distributed sources or transfer sources relatable to the ISO 6980-1996 sources.

Instrument correction factors shall be determined with an accuracy of ±20%.

At least one correction factor should be checked annually or after any modification or repair that may affect the correction factor.

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NOTE—The geometry at the source (point vs. distributed) used for the calibration shall be stated. For distributed sources, the geometry and dimensions of the source detector distance used shall be provided to enable the user to make corrections for field conditions.

6.1.6 Digital/analog readout

Calibration of both digital and the analog scales shall be performed.

6.2 Surface contamination measurement instruments

Alpha and beta-gamma detection instruments normally consist of two assemblies (a count rate meter and a detector). It shall be permissible to calibrate either the electronics and the detector together using radiation sources traceable to NIST, or the electronic package and the detector separately using an electronic pulser and radiation sources.

In addition to the criteria described in 6.1, the conversion factors for beta and alpha detectors should also consider the following (ASTM E1893-1997 [B9]):

1) The distance between the calibration source and the detector must be the same as the distance that will be used to quantify the in-situ field activity.
2) For quantifying a point source, a “point source efficiency” should be used with the conversion factor.
3) For quantifying a distributed source, a “surface source efficiency” should be used. The surface source used to determine the conversion factor should match the size and shape of the detector probe window area and should be at least as large as the probe face or at least 100cm^2, which ever is smaller.

Where the instrument is calibrated as an integral unit, a minimum of one point on each scale shall be calibrated up to 10 Bq/cm^2 (~6×10^4 dpm/100 cm^2). If each scale has a calibration potentiometer, the reading shall be adjusted to read the CTV at approximately 80% of full scale, and the reading at approximately 20% of full scale shall be observed. If only one calibration potentiometer is available, the reading shall be adjusted at mid-scale on one of the scales, and readings on the other scales shall be observed. Readings shall be within 20% of the CTV.

Where the electronic package and detector are calibrated separately, the count rate meter shall be calibrated with the electronic pulser. The detector shall be calibrated radiologically with sources traceable to NIST. When dead-time correction is supplied, it should be disabled when calibrating with a pulser and reengaged when calibrating with a source.

The exchange of probes with a count rate meter not used for the probe calibration is not recommended. The range of acceptable count rates for a specific check source shall be documented. If the exchange of probes is permitted, the new detector shall respond within the same range of acceptable count rates as the previous probe using the same check source as used with the original probe.

The counting efficiency or relationship (e.g., χ cpm/dpm) shall be documented on the detector after each calibration, or on the instrument if the probes are not exchanged in the field.

6.2.1 Beta-gamma contamination measurement instruments

Counting efficiencies should be determined for the type of activity expected to be measured. Where mixed or unknown contamination is to be measured, a number of different radionuclides with different energies, including low-energy photons, should be utilized. The distance from the source to the face of the detector shall be included with the recorded counting efficiencies.

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Where Geiger-Mueller counter tubes (GM) are used as detectors, the unit shall be tested to ensure that saturation dose not occur unless the maximum indicated value of the instrument is exceeded by at least a factor of two. The instrument shall continue to indicate a full-scale reading until the radiation field is reduced to less than the maximum display value. Digital readouts shall convey that the radiation level present exceeds the upper measurement level of the instrument in a manner described by the instrument manufacturer.

6.2.2 Alpha contamination measurement instruments

All detectors shall be checked for mechanical defects, such as light leaks or holes in the window material and/or scratches and cracks in scintillation material before calibration is initiated. A maximum acceptable background count rate shall be determined, documented, and used to test instrument prior to calibration.

Counting efficiencies shall be determined with the radionuclide to be detected, if possible, or with a radionuclide with similar energy.

7. Records

Records shall be maintained of all calibration, maintenance, repair, and modification data for each instrument. The record shall be dated and shall identify the individual performing the work. The record shall be filed with previous records on the same instrument and shall be readily retrievable. ANSI N13.6-1999 [B4] provides additional information.

7.1 Instrument information

7.1.1 Instrumentation information labeling

Each instrument shall be labeled with the following information:

a) Date of most recent calibration.
b) Initials or other specific identifying mark of calibrator.
c) Date that primary calibration is again required.
d) Special-use or limited calibration label (if applicable).
e) Serial number of the instrument or the other unique identification number used by the facility to identify a specific instrument.

7.1.2 Additional instrumentation documentation

The following information shall be documented and made available to the user for each instrument:

a) Energy correction factors, where appropriate.
b) Graph or table of calibration factors, where necessary, for each type of radiation for which the instrument was calibrated. This should relate the scale reading to the units required if units are not provided on the scale.
c) Instrument response to an identified check source (to be provided either by calibrator or user).
d) Unusual or special use conditions or limitations, where appropriate.

7.1.3 Additional calibration source information

The following descriptive information for the calibration source used by the calibration laboratory should be provided with the instrument. This information has direct applicability to converting laboratory calibration factors to field measurement interpretation.

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a) Physical description of the calibration source(s) used; include radionuclides and physical dimensions of the active area of the source.
b) Encapsulation or planchet dimensions for surface activity sources; include the material composition of covering or encapsulation and backing material of surface activity calibration sources.
c) Suppliers certification of the source activity and a statement of the uncertainty of the total source activity or emission rate.
d) Value of the maximum error or uncertainty in the probe efficiency vs. source location distance from the center of the probe for surface activity instrument calibrations that use a source of area dimensions less than the active area of the probe.
e) Distance from the active source surface to the surface of the probe window for surface activity measurement calibrations.
f) State whether the efficiency for the surface activity calibration is for 2π or 4π emission.

NOTE—The calibration source descriptive information may be provided by including a copy of the source supplier calibration certification sheet.

7.2 Facility documentation

A comprehensive and readily available record system shall be maintained by the calibration facility. All records of data shall identify the individual who collected the data on which the record is based. The record system shall include at least the following:

a) An inventory of all standards and calibration equipment.
b) A full history and calibration data, including certificates, for all standards and applicable calibration equipment.
c) All procedures used for providing calibration services.
d) Routine quality control records.
e) The results of all performance testing.
f) Records of instrumentation for which a calibration service was provided, and the date that the calibration was performed including a description, sufficient for identification, of every item. The record system shall also include or reference a detailed report for that specific calibration.
g) Copies of all calibration reports issued and/or all electronic records.
h) Information essential to the analysis and reconstruction of the calibration of a specific item of instrumentation.
i) Records detailing the education, experience, and training of all operating staff and supervisory personnel.
j) A documented analysis of calibration uncertainties.

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Annex A

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Tests performed with variation of influence quantities

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

Characteristics under test (influence quantity)	Range of values of influence quantities	Limits of variation	ANSI N42.17A-1989 [B7] Method of test (clause)
Electronic and mechanical tests			
Battery power	0 – 100 h	10%	4.11.2
Check circuits	Per manufacturer's recommendations	—	5.1.2
Stability	Battery powered: 3 h	6% reference initial reading	5.3.2
Geotropism	Test in all spatial orientations	6% reference standard orientation	5.4.2
Response time	See Table 3	See Table 3	5.5.2
Coefficient of variation	≥ 1 mR/h, 1 mrad/h, 10 mrem/h, 2000 dpm < 1 mR/h, 1 mrad/h, 10 mrem/h, 2000 dpm	10% 15%	5.6.2 5.6.2
Radiation response			
Accuracy, photon dose rate	10 µR/hr – 10 mR/hr	±10 from conventionally true value	6.1.2.1
Accuracy, count rate, and contamination monitors	50 dpm/cm^2 – 10^4 dpm/cm^2	±10 from conventionally true value	6.1.2.2
Accuracy, beta dose rate	10 µrem/hr – 10 mrem/hr	±10 from conventionally true value	6.1.2.3
Photon energy depedence	(1) 80 keV to 1.25 MeV	$0.8 \leq \frac{(r_{eni}/CTV_{eni})}{(r_{ref}/CTV_{ref})} \leq 1.2$	6.3.2
	(2) 20 keV to 3.0 MeV	Same as above	6.3.2
Beta energy dependence	(1) 0.5 MeV to 3.5 MeV (E_{max})	$0.5 \leq \frac{(r_{\beta i}/CTV_{\beta i})}{(r_{\beta ref}/CTV_{\beta ref})} \leq 1.5$	6.4.2
	(2) 0.2 MeV to 3.5 MeV (E_{max})	Same as above	6.4.2
Photon radiation overload	100 times upper limit ≤ 10 rad/h 10 times upper limit > 10 rad/h	Correct response within 2 min	6.6.2
Angular dependence	0° – 45° (photon) 45° – 90° 0° – 45° (beta)	< 20% change in reading < 50% change in reading < 50% change in reading	6.7.2 6.7.2

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

Characteristics under test (influence quantity)	Range of values of influence quantities	Limits of variation	ANSI N42.17A-1989 [B7] Method of test (clause)
Interfering response			
Extracemeral response	Range of instrument	5% reference standard orientation	7.1.2
RF fields	(1) Per user requirements (2) 100 V/m, 0.3 to 35 MHz (3) 100 V/m at ~ 140 MHz	5% reference standard conditions 15% reference standard conditions 15% reference standard conditions	7.2.2 7.2.2.1 7.2.2.2
Microwave fields	(1) Per user requirements (2) 100 W/m^2 at 915 MHz, 2450 MHz	15% reference standard conditions 15% reference standard conditions	7.3.2 7.3.2
Electric fields	(1) 5000 V/m (2) 100 V/m at 60 Hz, 400 Hz	15% reference standard conditions 15% reference standard conditions	7.4.2.1 7.4.2.2
Magnetic fields	800 A/m	15% reference standard conditions	7.5.2
Interfering radiation	See Table 5	—	7.6.2
Environmental factors			
Temperature	(1) 0 °C – 40 °C (2) –10 °C – 50 °C (3) 10 °C – 35 °C	15% reference 22 °C 20% reference 22 °C 15% reference 22 °C	8.1.2 8.1.2 8.1.2
Temperature shock	(1) –10 °C from / to 22 °C (2) 50 °C from / to 22 °C	15% reference 22 °C 15% reference 22 °C	8.2.2 8.2.2
Humidity	40% RH to 95% RH (T = 22 °C ±2 °C	15% reference, 40% RH	8.3.2
Mechanical shock	50 g acceleration of 18 ms, half sinewave, test on 3 orthogonal axes, 10 times	15% reference standard conditions	8.4.2
Vibration	2 g acceleration, frequency range of 10 – 33 Hz, test on 3 orthogonal axes for 15 min	15% reference standard conditions	8.5.2
Ambient pressure	70 – 106 kPa	15% reference, 101 kPa	8.6.2
Splash proof	2 min fine spray (4 L/min 2 m from nozzle)	15% reference standard conditions	8.7.2

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Annex B

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[5]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/).

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