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American National Standard for Installed Radiation Protection Instrumentation

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

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American National Standards Institute

Secretariat

The Institute of Electrical and Electronics Engineers, Inc.

Approved 3 September 2002

American National Standards Institute

Abstract: Requirements for installed instruments that measure dose, dose rate, and equivalent dose or dose rate and for installed instruments that detect or measure radioactive contamination are established.
Keywords: dose, dose equivalent, dose rate, installed instrumentation, instrumentation, radiation, radiation protection

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American National Standard

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Introduction

(This introduction is not part of ANSI N323D-2002, American National Standard for Installed Radiation Protection Instrumentation.)

This standard is the responsibility of the Accredited American National Committee on Radiation Instrumentation, N42. Committee N42 delegated the 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 ballot of 3 September 2002.

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American National Standard for Installed Radiation Protection Instrumentation

1. Scope

This standard establishes specific requirements for installed instruments that measure dose, dose equivalent, dose rate, or dose equivalent rate and for installed instruments used to detect and/or measure the presence of radioactive contamination. This standard does not address criticality detection systems.

For this standard, installed radiation protection instruments are instruments that operate using line power primarily. They are also *not* hand-carried during use, and they are typically operated at a fixed location. Instrument types include, but are not limited to, area, equipment, sample, personnel, and waste monitors.

Special purpose instrumentation, such as emergency post-accident radiological monitors, fall under the scope of other related ANSI standards. This standard is intended to supplement rather than replace them.

Low-range (i.e., near background to < 10 μSv/h) instruments, air monitors, and air samplers are addressed by ANSI N323B and ANSI N323C, respectively.

Throughout this standard, three verbs have been used to show 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.

2. Definitions

Technical terminology used in this standard is generally consistent with the definitions in ANSI N1.1-1976 [B1][1] and ICRU 60-1998 [B7] as well as IEC 60050-394-1995 [B8]. The following terms are defined specifically for use within this standard.

2.1 absorbed dose: The amount of ionizing energy absorbed in matter. The unit of absorbed dose is the gray**.**

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

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

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2.3 accuracy: The degree of agreement, when comparing the observed value with the conventionally true value of the quantity being measured.

2.4 adjust: To alter the response by a variable built-in control (e.g., potentiometer, software).

2.5 calibrate: 1) To adjust or determine the response or reading of an instrument relative to a series of conventionally true values; or 2) to determine the activity of a radiation source relative to a standard or conventionally true value.

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

2.7 check source: A radioactive source, not necessarily calibrated, which is used to confirm the continuing satisfactory operation of an instrument.

2.8 contamination detector: An assembly including one or several radiation detectors and associated assemblies designed to detect (alpha, beta, photon) contamination.

2.9 conventionally true value (CTV) of a quantity: The commonly accepted best estimate of the value of that quantity. This and the associated uncertainty should be determined by a national or secondary standard, or by a reference instrument calibrated against a national or transfer standard, or by measurement quality assurance (MQA) with National Institute of Standards and Technology (NIST).

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

2.11 counting efficiency: The ratio between the net (gross minus background) instrument reading and the surface emission rate or activity of a source under given geometrical conditions. The value is typically expressed as a percentage.

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

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

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

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

2.16 dose equivalent: The product of the absorbed dose, quality factor, and all other necessary modifying factors at the point of interest in tissue. The unit of dose equivalent is the sievert.

2.17 dose rate: The radiation dose delivered per unit of time, measured, e.g., in sievert per hour.

2.18 energy dependence: Variation in instrument response as a function of radiation energy for a constant radiation type.

2.19 extracameral: Pertaining to the portion of the instrument exclusive of the detector.

2.20 functional check: Checks (often qualitative) made to determine whether an instrument can perform its intended function. Such checks may include alarm relay and operability, battery check, electronic diagnostics, or source response.

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

2.22 indicated value: A scale or decade reading; the displayed value of the readout; the reading.

2.23 installed instrument: A radiation instrument that is primarily powered from a mains (line) source and that is typically located at a facility or area either permanently or semipermanently. These instruments are commonly used to detect the presence of radioactive contamination on equipment or personnel or to monitor the existing conditions for changes in radiation levels.

2.24 instrument: A complete system consisting of one or more assemblies designed to detect the presence of radioactive contamination or to quantify other characteristics of ionizing radiation.

2.25 measurement uncertainty: An estimate of the range of values within which the true value of the measurement lies, usually centered on the nominal or indicated mean value.

2.26 performance test: An evaluation of the instrument's performance in response to a given influence quantity.

2.27 qualify: To describe the qualities or characteristics (i.e., radiation type) of the item being surveyed or analyzed.

2.28 quantify: To measure the type and amount of radioactivity or radiation.

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

2.30 reading: The indicated value of the readout.

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

2.32 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.

2.33 reference point: A mark (or markings) on the outside of an instrument or detector used to determine the effective center of the sensitive volume of the detector.

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

2.35 reproducibility (precision): The degree of agreement of repeated measurements of the same property expressed quantitatively as the standard deviation computed from the results of the series of measurements.

2.36 response: The instrument reading produced as a result of some influence quantity.

2.37 response time: The time interval required for an instrument reading to change from 10% to 90% of the final reading (or vice versa) following a step change in the radiation field at the detector.

2.38 sensitivity: An instrument's ability to indicate that a change in measured activity has occurred at a specified confidence level.

2.39 source response check: The check of instrument response to a source to determine whether the instrument is still functional within an acceptable range. This check can include the use of ambient background radiation.

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2.40 standard (instrument or source):

a) **national standard:** An instrument, source, or other system or device maintained and promulgated by the National Institute of Standards and Technology (NIST).
b) **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.
c) **laboratory standard:** An instrument, source, or other system or device calibrated by comparisons with a standard other than a national standard.

2.41 overload response: The response of an instrument when exposed to radiation intensities greater than the upper detection limit.

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

3. General requirements

3.1 Operational characteristics

The operational characteristics of an instrument, as defined by a series of type tests, will indicate how accurately the instrument can be expected to measure radioactivity levels under anticipated operational conditions. Variations in radiation energy, radiation direction, line voltage, temperature, humidity, instrument stability, etc. can affect the accuracy of measurements in the field. Performance criteria and test methods set forth in the ANSI N42.17 series should be used as a guide in establishing installed-specific criteria until a test standard is available. Once the operational characteristics are defined for an instrument model via type testing, each instrument shall be acceptance-tested for critical requirements to assure that the instrument performance is representative of the requirements set forth by the user.

For large numbers of instruments it shall be considered acceptable to establish statistical criteria for testing and accepting instruments. However, basic functional tests (e.g., response verification, alarm activation) should be performed on each instrument. Instruments shall be type-tested for variables critical to their performance in the intended environment and shall be acceptance-tested prior to calibration and initial use.

Where guger-mueller (GM) tubes are used as detectors, the unit shall be tested to ensure that the detector remains operational when exposed to radiation levels that are less than or equal to twice the maximum indicated value of the instrument. The instrument shall continue to indicate a full-scale reading and remain so 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.

3.2 Acceptance tests

An acceptance test shall consist of

— Physical inspection
— General functionality tests
— Source tests

An acceptance test should precede the initial instrument calibration. A physical inspection and general functionality test shall be performed on each instrument. Source tests should be performed on a random selection

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of an instrument lot. Test failures should be evaluated to determine the cause and the need for any follow-up actions.

3.2.1 Physical inspection

A physical inspection is an inspection identifying any physical abnormalities that may affect instrument operation. This step may include inspecting for broken parts, loose or missing screws, loose or misaligned knobs, calibration potentiometers not aligned with access holes, circuit board workmanship, loose wires, loose connectors, loose components, etc.

3.2.2 General functionality tests

General functionality tests determine nonradiological operating functions, e.g., remote outputs operation, alarm operation, status indicator operation, and back-up battery check condition.

3.2.3 Source tests

Source tests determine radiological operating functions. Testing shall include radiation response and may include angular dependence, variability of readings, stability, temperature susceptibility, humidity susceptibility, susceptibility to electromagnetic fields, static discharge, or photon energy response. Temperature, humidity, line-voltage variation, and energy response tests may consist of single data points at extremes of these variables to test against specifications.

3.3 Performance tests

Instruments shall be tested periodically to ensure that they continue to operate as expected based on the instrument's type testing results. Unless the response to a specific influence quantity is being tested, performance tests shall be done under a group of controlled conditions called *standard test conditions*, which can be found in Table 1.

Table 1—Standard test conditions (normative)

Influence quantities	Acceptable range for standard test conditions
Warm-up time	> 1 minute or manufacturer's specification
Relative humidity	Ambient, not to exceed 75%
Ambient temperature	20 °C to 24 °C
Atmospheric pressure	70 kPa to 106 kPa
Background ambient photon radiation (external)	Less than 2.5% of full scale of the range or decade under test, but nominally should not exceed 0.5 μGy/h, 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 within applicable limits (site or regulatory)

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3.4 Routine function tests

Routine function tests assure that instruments continue to meet their performance requirements during use. A function test shall be performed after any maintenance or repair that could affect the functionality of the monitor. The test can be performed manually or automatically depending on the capability of the instrument. Any automatic function check routine used as a replacement for manual testing shall be evaluated prior to use.

3.5 Source response check

To assure proper operation of the instrument between calibrations, each instrument shall be routinely checked with a source during operation. The response check frequency should be increased where instruments are subjected to extreme operational conditions, hard usage, etc.

If at any time the instrument response to the source differs from the reference reading by more than ± 20% or the value specified by the manufacturer, whichever is smaller, the instrument shall be removed from service for evaluation. An evaluation is required based on the possibility that the change in response may be caused from changes in ambient background or other environmental conditions that affect an installed instrument's response, not necessarily from a problem with the instrument itself.

Reference readings shall be obtained for each instrument when exposed to a source in a constant and reproducible manner at the time of calibration or shortly thereafter. Where it is shown that readings for a specific model of instrument fall within ± 20%, it shall be permissible to obtain generic reference readings for a given source. The source should accompany the instrument if it is specific to that instrument.

NOTE—A source response check may not be practical for some instruments such as high range and neutron exposure rate instruments. In these cases, the facility should develop compensatory methods to demonstrate that the instrument is operable before use.

Check sources should provide radiation of the same type or types as provided by the sources used in instrument calibration described in 5.1. However, check sources may provide radiation different from the radiation used for calibration if

— The source/instrument geometry is well established, well understood, and easily reproduced, and
— The instrument response to this radiation is well understood and is not dependent on instrument adjustment. For example, the use of a beta source to check instruments sensitive to photon radiation may be acceptable while the use of a photon source to check a detector utilizing a BF_3 tube is not acceptable.

An instrument's response to ambient background radiation may be used in lieu of a check source provided

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

3.6 Enhanced capabilities

Enhanced capabilities enable an instrument to measure and store background radiation levels for use in the determination of net count rate, activity alarm points, and problem indication, as well as detector efficiencies

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for activity level determination. This type of instrument may also have the capability to compensate for radon and allow the monitoring of more than one radiation type, such as alpha and beta, simultaneously. Other enhancements may involve the calibration of the instrument. All enhanced capabilities should be evaluated prior to use for radiation protection.

3.7 Special use conditions

If the instrument is to be used for conditions other than the conditions for which it was tested, such as energy range or environmental conditions, calibration or performance testing for these conditions shall be performed. Similarly, if the instrument is physically altered so that the previous calibration and performance tests could be invalidated, calibration and re-testing shall be performed. Where calibration or performance tests are performed under several variables, such as temperature or humidity, only one variable should be varied while other conditions are held constant.

3.8 Instrument repair

Instrument repair shall be performed using components that are equivalent to components specified by the manufacturer. Manufacturer-provided repair instructions should be reviewed prior to use. Repair instructions should be developed and reviewed if not provided by the manufacturer. Certain repairs or modifications made using nonequivalent components constitute an instrument modification that may invalidate any premodification type tests. Repairs and/or modifications shall be evaluated to determine whether type testing or calibration is required prior to field operation.

4. Calibration

This clause describes the calibration requirements for installed radiation protection instruments. Generic requirements are discussed, followed by specific requirements for dose rate and contamination instruments.

4.1 Precalibration

Prior to calibrating an instrument, the following actions shall be performed: inspection and response verification.

4.1.1 Inspection

The instrument shall be inspected to ensure that its physical condition is acceptable. The inspection should include visually checking the condition of any external wires or cables, cleanliness, gas supply (when necessary), back-up battery, etc.

If the instrument has detectors that use thin material as windows, each window should be checked for light leaks or holes.

4.1.2 Response verification

The response test shall ensure that the radiation response of the instrument has not degraded. The response of the instrument should be within a tolerance based on the response of the instrument in the same geometry determined shortly after the calibration. If the response test is within tolerance, it shall be permissible to return the instrument to operation.

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4.2 Calibration

A calibration shall include adjustment and/or determination of new readings for each point selected or confirmation of previously determined responses on the scale or range of interest. Electronic calibration shall 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.

If the instrument uses a digital and analog readout, both readouts should be calibrated. If one or the other is not calibrated, it shall be noted on the instrument.

The response test acceptance range should be established as part of the calibration or as a separate step performed as soon as possible after the calibration.

The following conditions shall be established prior to exposing the instrument to a source for adjustment and calibration:

— The instrument shall be turned on and allowed to stabilize.
— Electronic adjustments, such as high voltage or discriminator thresholds, shall be set to the site or manufacturer's specifications, as applicable.

4.2.1 Dose and dose rate

4.2.1.1 Linear readout

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. If the instrument uses a menu-selection technique to select a calibration factor, the same principle shall be applied.

NOTE—If instruments have ranges that are not calibrated, a tag shall be attached to the instrument noting the limits of calibration.

After adjustment, the response shall be checked near the end points of each scale at approximately 20% and 80% of full scale or instrument range. Instrument readings shall be within ± 15% of the conventionally true values (CTV) for the lower point and ± 10% CTV for the upper point.

NOTE—For instruments that have been proven linear through type testing and/or acceptance testing, it is necessary to check only the response at the points specified by the manufacturer and at approximately 20% and 80% of the detector's range or the user's range of interest. If the full range is not intended for use, the range calibrated shall be noted on the instrument.

4.2.1.2 Logarithmic readout

Logarithmic readout instruments that have a single readout scale spanning several decades normally have two or more adjustments. The instrument shall be adjusted according to the user's or 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 impact on accuracy are documented and justified.

After adjustment, the response shall be checked at a minimum of one point on each decade and instrument readings shall have a maximum 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, 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.

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4.2.1.3 Digital readout

Digital instruments shall be calibrated as in 4.2.1.1. If the instrument is designed to autoscale, the calibration point should be selected far enough from the autoscaling point that autoscaling will not affect the reading.

Instruments should be cycled through a complete test of all display segments or indicators either electronically or radiologically.

4.2.1.4 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 range is not intended for use, the range calibrated shall be noted on the instrument.

The integrated dose shall be within 15% of the CTV of the expected dose.

For digital instrumentation, the integrate function should be checked to the maximum reading obtainable on the display or to the maximum level of use. If it is not practical to accomplish a full-scale radiological integration, the instrument shall be checked electronically to the appropriate maximum integration point with the lower point checked radiologically. If the instrument is not checked over its entire range, it shall be tagged to indicate its limitations of use. See 6.3.3 for more information.

4.2.1.5 Neutron dose equivalent instruments

Instruments designed to read out in units of neutron dose equivalent, or dose equivalent rate, shall be calibrated following the guidance found in 4.2.1.1 through 4.2.1.4. The calibration accuracy for ranges from 0 to 100 μSv/h or 0 to 100 μSv shall be ± 30%. The accuracy for ranges from 100 μSv/h or 100 μSv and above shall be within ± 20%.

4.2.2 Contamination instruments

Contamination instruments consist of integral or separate detectors and integral or separate counting circuits. A digital or analog readout, or both, can display measured count rates or other information pertinent to the user. An instrument may consist of single or multiple detectors that can be calibrated to single or multiple radiation types (alpha, beta, and gamma). Enhanced operating features (e.g., active background compensation, statistical counting analysis, automatic failure detection) shall be evaluated prior to use to ensure applicability. Instruments that consist of many detectors with the ability to monitor for many radiation types are calibrated using the same technique as single-detector, single-radiation contamination instruments.

Scintillation detectors shall be checked for light leaks, and air- or gas-proportional detectors shall be checked for holes in the window material prior to calibration. An acceptable background count rate range shall be documented and used to test instruments prior to calibration.

4.2.2.1 Radiological calibration

The detectors shall be calibrated using sources traceable to NIST with the resultant information (correction factors, efficiency, and geometry limitations) available to the user through an attached tag or other means. Calibration sources should represent the type and energy of radiation that is anticipated. The error associated with source counts obtained for detector efficiency determination should be limited to 1% or less, where the error is equal to the square root of the total counts obtained divided by the total counts obtained.

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When an instrument is used to *qualify* contamination levels, a minimum of one point on each scale shall be calibrated either electronically or with a source. Correction factors, geometry, or other detector response specifics are not required.

When an instrument is used to *quantify* contamination levels, the counting efficiencies or relationship, × counts per minute (cpm)/disintegrations per minute (dpm), based on the counting geometry and radionuclide of interest shall be documented. If the radionuclide of interest is not available for calibration, the instrument should be calibrated using a radionuclide with an energy that is less than or similar to the radionuclide of interest. The instrument should not be used to quantify contamination levels when the counting geometry is inconsistent.

When an instrument is used to determine 4π-activity from an obtained count rate, the calibrator should be aware of the differences in backscatter and self-absorption effects between the efficiency source and the surface to be monitored. If the values associated with the surface to be monitored are unknown or inconsistent, the source *surface emission rate* should be used for efficiency determination. The surface emission efficiency shall be corrected, multiplied by 0.5 or divided by 2, to estimate the 4π-emission rate of the monitored surface independent of radiation energy. The technique used shall be documented.

When calibrating instruments for volumetric contamination levels, detector efficiency shall be determined using the 4π-emission rate with the source placed within objects that provide expected scatter and shielding effects.

4.2.2.2 Electronic calibration

Calibration controls, such as high voltage, amplifier gain, and discriminator thresholds, should be adjusted according to the manufacturer's recommendations. If settings other than the manufacturer-recommended settings are used, the basis shall be evaluated and documented.

When dead-time correction is provided, it should be disabled when calibrating with a pulse generator.

Enhanced calibration techniques shall be evaluated prior to use. This evaluation may include computer-based calibration software or inherently linear instrument designs.

4.2.3 Field calibrations

With stationary instruments, calibrations are often done where the instrument operates. Environmental conditions at the location of use may not be controlled to the levels stated in Table 1. If the field conditions are stable, calibration quality should remain as high as calibrations performed in controlled environments. If conditions are not stable, limits as to the variability of each condition shall be known and stated in the specific instrument calibration procedure. Limiting conditions will typically include temperature, humidity, and ambient background, as a minimum.

When doing field calibrations, source placement should be within close proximity of the detector to reduce the uncertainties created by scatter. Background attenuation caused by calibration assemblies shall be considered when making measurements.

Field calibrations shall be traceable to the NIST based on the requirements stated in 5.1.

4.2.4 Calibration for special conditions

When an instrument is to be adjusted and calibrated for use only under special conditions (including radiation energy, temperature and pressure, or source/detector geometry), a special use identification label or other means of identification shall be attached in addition to any required calibration labels to indicate its applicability *for this special use*. If the instrument is also to be used within its design limits, calibrations

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shall be done under standard conditions (Table 1), and instrument readings shall be corrected using factors derived from the instrument's response under special conditions. The basis for the calibration to special conditions shall be documented.

Determination of revised correction factors shall be performed when

— The instrument is modified or physically altered
— The special conditions are changed
— The routine calibration suggests a change or deterioration has occurred in instrument performance

4.3 Discrimination against interfering radiations

The effect of ionizing and non-ionizing radiation interferences shall be documented based on the conditions of use. Results should be available to document instrument discrimination against a range of ionizing and non-ionizing radiation interferences. If adjustments or changes are made that could alter the instrument response to interfering ionizing and non-ionizing radiations, the discrimination against interfering radiation shall be determined for all interfering radiation types that may be encountered.

4.4 Detector geometry dependence

If dose/dose equivalent rate instruments are used under conditions that do not uniformly irradiate the detector volume (e.g., when the instrument is too close to a source or in a beam), the instrument response may vary significantly with source geometry, source energy, detector geometry, and detector distance. Correction factors shall be provided to enable the user to make field corrections.

4.5 Detector interchangeability

The exchange of detectors without recalibration shall be permitted if the variation between individual detectors has been documented to be within 20% of the CTV. The new detector shall respond within the same acceptable count rate range as the previous detector when using the same check source.

5. Calibration equipment

5.1 Calibration standards

Instruments shall be calibrated with appropriate standards that are traceable to the NIST. Where no national or secondary standard exists, as in the case of specific energies, unusual sources, or unusual source configurations, a derived standard shall be established using documented empirical and theoretical information or response characteristics.

If the source is a radionuclide, the half-life should be long, preferably greater than several years to minimize corrections and uncertainties. Suggested isotopes are listed in Table 2 along with a list of appropriate standards. Radionuclide sources used for contamination instruments should be selected based on the relevant isotopes and other monitoring requirements present within a specific facility.

Calibration fields shall be characterized and documented in terms of quantity and reproducibility. Such considerations as charged particle equilibrium, scattered or unwanted radiations from the source, and ambient background radiation should be accounted for during standardization of the calibration assembly. Source uncertainties shall be within the limits stated in Table 3.

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Table 2—Reference sources for calibration (informative)

Radiation type	Reference source	Reference
Gamma	^{137}Cs,[a] ^{60}Co,[a] ^{241}Am	ISO 4037-2-1997 [B11] ISO 4037-3-1999 [B12] ANSI N42.17A-1989 [B3]
X-ray	M30,[a] H50,[a] H100,[a] H150,[a] H200,[a] H250,[a] H300,[a] M150	NBS Spec. Pub. 250-1989 [B20]
X-ray (K fluorescence)	16, 24, 34, 43, 58, 78, 100 keV	ISO 4037-2-1997 [B11] ISO 4037-3-1999 [B12]
Neutron	^{252}Cf,[a] ^{241}Am-Be[a] $^{252}Cf+D_2O$ Moderator	ISO 8529-1989 [B14] ANSI N42.17A-1989 [B3]
SURFACE contamination		
Alpha	^{241}Am, ^{230}Th,[a] ^{239}Pu[a]	ISO 8769-1988 [B15] ANSI N42.17A-1989 [B3]
Beta	^{90}Sr-^{90}Y,[a] ^{14}C, ^{147}Pm, ^{36}Cl , ^{99}Tc ^{204}Tl,[a] ^{106}Ru-^{106}Rh, U-Nat, U-Dep	ANSI N42.17A-1989 [B3]
NOTE—For larger area beta or alpha detectors, the detector-source response factor should be based on contact with the detector "face."		

[a]Reference source for instrument type testing, ANSI N42.17A-1989 [B3].

Table 3—Calibration field accuracies[a] and quantities

Radiation type	Accuracy (95% confidence interval)	Quantity
Gamma	5%	Deep dose equivalent
X-ray	5%	Deep dose equivalent
Neutron	10%	Deep dose equivalent
Beta	10%	Shallow dose equivalent
Alpha contamination	10%	Activity/unit area
Beta contamination	10%	Activity/unit area

[a]Accuracies are for dose rates greater than 100 μGy/h, 100 μSv/h or 10^3 Bq/cm^2.

Fields used for instrument calibration should be such that a uniform fluence exists throughout the entire volume of the detector, where appropriate. The use of sources that are much smaller than the sensitive surface of the detector is permitted for contamination instruments that use large area detectors with source-to-detector distances based on the instrument's application.

Quality control procedures shall be in place to assure that the working and derived standards maintain a known relationship with national or secondary standards.

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5.2 Calibration assemblies

Assemblies used to hold or position either the source or instrument shall be mechanically precise to ensure that positioning uncertainties do not affect the radiation field values. Calibration assemblies should be designed in such a way to keep scatter or attenuation to a minimum.

6. Calibration quality

6.1 Calibration facility

When free-in-air geometry is utilized for photon and neutron instrument calibration, the distance to 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 stated in Clause 4.

The radiation background at the calibration facility shall be low, known, and stable and shall be accounted for during calibration. The environment within the calibration facility should be maintained within the limits of standard test conditions as noted in Table 1.

6.2 Calibration frequency

The calibration frequency depends on the stability of the instrument. Stability can be indicated through the results of routine response checks. If an instrument's routine response check results consistently fall within ± 10% of the response obtained at, or shortly after, calibration, no recalibration is required. If the routine response check is between ± 10% and ± 20%, recalibration shall be required at least annually.

As-found readings obtained prior to adjustment shall be documented to demonstrate the response of the instrument upon return to the calibration facility. If greater than 10% of the instruments are out of calibration, a review of the response check procedure and calibration interval should be considered as well as an evaluation of the quality of the instrument model.

6.3 Records

6.3.1 Calibration records

A record shall be maintained of all calibration, maintenance, repair, and modification data for each instrument. ANSI N13.6-1996 [B2] provides additional information.

Each calibration record should contain information regarding the environmental conditions (e.g., temperature, humidity, and atmospheric pressure) if appropriate to the calibration.

6.3.2 Instrument information

The following information shall be available for each instrument or model, as appropriate:

- Date of last calibration and who performed the calibration
- Date of next calibration
- Energy correction factors
- Graph or table of calibration factors
- Instrument response to an identified check source
- Unusual or special use conditions or limitations

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6.3.3 Instrument labeling

When an instrument is designated for special or limited use, a label or other means of indication shall be attached to the instrument in an appropriate manner to identify the specific use or limitation.

Because installed instruments may be made up of separate components, it may not be practical to attach a label indicating such things as calibration date and calibration due date on each component. If a label is desired, it should be attached at a location that is typically viewed by a user.

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Annex A

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Automated contamination instruments

A.1 General

This annex provides information regarding multidetector, multiradiation monitors that are used to quantify or qualify contamination levels. The monitors addressed are typically microprocessor-based and contain user-entered values regarding operational functions, such as count time, alarm confidence, functionality verification. Specific requirements are not addressed in this annex.

A.2 Calibration sources

Calibration 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 (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 α/sec or β/sec. Activity is quoted in becquerels.

The calibrator 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 a source 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.

A.3 Enhanced multidetector instruments

Enhanced multidetector instruments typically have the capability to perform many operations automatically, without user intervention. Although this type of instrument appears complicated, its calibration is essentially the same as single-detector, single-radiation instruments. Operating and data manipulation parameters require a more detailed explanation. Table A.1 describes some of the more common features and compares the principle differences between simple and more complex instrument types.

A.4 Contamination levels

Contamination alarm levels are generally driven by regulatory authorities or site requirements. However, selection of detection confidence or certainty values based on the *probability of detection* or confidence level and false-alarm rates or *probability of false alarms* are often local decisions. The effects of these values can significantly impact monitoring time and equipment credibility with the users. High false-alarm rates can quickly reduce user confidence in the integrity of the measurement while too stringent statistical requirements extend monitoring times resulting in low throughput and frustrated workers.

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Table A.1—Common features of various instruments

Feature	Analog or simple digital	Multidetector of enhanced system
User interface	Simple display consisting of lamps and sounder. Typically set up using DIP switches and/or manual potentiometers.	Interactive, full color, large display with numerous input and output options. Typically set up using a keypad or keyboard.
Background compensation	None, or rudimentary sample and hold background subtraction.	Advanced background sampling, storage, and subtraction with the capability to analyze and modify operational parameters.
Statistical analysis	None, or simple go/no-go on high background limit with manual offset for confidence levels.	Multiparameter user entered, and/or instrument calculated values for probability of false alarm, probability of detection, attenuation (self-shielding or scattering), changing background, minimum and maximum counting time, and multiple alarm set points.
Advanced features	None.	Fault recognition and analysis, automatic contamination check, recount on alarm, summation between adjacent detectors, radon compensation, etc.

Automated alarm set points can be entered in terms of activity (becquerels) or by count rate (C) above background after modification by the averaging area and the 4π efficiency {C = alarm activity per unit area × averaging area × detection efficiency (4π)}.

An important consideration is the geometry of the source to the surface of the detector. It may be appropriate for some instrument models to use contact efficiencies, whereas others may use some fixed source-to-detector distance based on local evaluations or industry practices. IEC 61098-1992 [B9] defines 50 mm as a reasonable distance to use based upon the vertical and horizontal body contours that, combined, give a body average efficiency equivalent to a 50 mm air gap. For other monitors, a facility- or individual-specific evaluation should be considered to determine the appropriate distance for use.

A.5 Statistical considerations

The type of monitors discussed in this annex typically require the use of factors to address probability of false alarm and probability of detection.

The *probability of false alarm* adjusts the user-entered alarm level to ensure that normal fluctuations in background do not cause an alarm while monitoring is performed. Counts obtained from additional background scatter generated by an individual or object during the monitoring cycle, radioactive material other than the material that is desired to be detected [e.g., naturally occurring radioactive material (NORM), radon], or equipment failures generating apparent alarms will usually continue to cause alarm activation. The chosen probability of false alarm value is typically 1 in 1000 measurements with the corresponding sigma level dependent upon the number of detectors in the instrument.

The *probability of detection* establishes the probability that exactly one alarm level of contamination will be detected. The rate of detecting exactly one alarm level of measured emissions is on average 50% or 0 sigma.

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A higher detection rate may be desired and can be achieved by modifying the alarm set point by the probability of detection. This effectively reduces the alarm level creating a lower alarm threshold. On many instruments, the monitoring time will automatically increase as the probability is increased.

A.6 Other features

Some instruments have the capability to correct a detector's response for attenuation (self-shielding) or scattering. Factors used shall be based on empirical proof that an individual or object is creating significant attenuation or scattering. An evaluation should be conducted with individuals or objects that are at the extreme ends of the range of sizes (e.g., very large and very small) before a feature, such as the ability to correct a detector's response, is enabled.

Another common feature is detector summation. This feature should be used if proven effective for the application intended. When enabled, the overall sensitivity of the monitor for distributed contamination is increased. An evaluation should be performed to verify this software feature's effectiveness.

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Annex B

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[B3] ANSI N42.17A-1989, American National Standard Performance Specifications for Health Physics Instrumentation—Portable Instrumentation for Use in Normal Environmental Conditions.

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[B6] ICRU 39-1985, Determination of Dose Equivalents Resulting from External Radiation Sources.[3]

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[B10] ISO 4037-1-1996, X and Gamma Reference Radiation for Calibrating Dosemeters and Dose-Rate Meters and for Determining Their Response as a Function of Photon Energy—Part 1: Radiation characteristics and production methods.[5]

[B11] ISO 4037-2-1997, X and Gamma Reference Radiation for Calibrating Dosemeters and Dose-Rate Meters and for Determining Their Response as a Function of Photon Energy—Part 2: Dosimetry for radiation protection over energy ranges 8 keV to 1.3 MeV and 4 MeV to 9 MeV.

[B12] ISO 4037-3-1999, X and Gamma Reference Radiations for Calibrating Dosemeters and Dose-Rate Meters and for Determining Their Response as a Function of Photon Energy—Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence.

[2]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/).

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

[4]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.

[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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[7]NIST 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/).

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