ANSI N42.20-2003
(Revision of
ANSI N42.20-1995)

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American National Standard Performance Criteria for Active Personnel Radiation Monitors

Accredited by the American National Standards Institute

Sponsored by the
National Committee on Radiation Instrumentation, N42

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Accredited by the
American National Standards Institute

Secretariat
The Institute of Electrical and Electronics Engineers, Inc.

Approved 22 August 2003
American National Standards Institute

Abstract: Performance and design criteria are provided in this standard for monitors that are worn on the trunk of the body to measure the personal dose equivalent, or the dose equivalent rate from external sources, of ionizing radiation.This is a revision of ANSI N42.20-1995.
Keywords: design criteria, ionizing radiation, monitors, performance criteria, personnel radiation monitors, radiation, radiation instrumentation, radiation monitors

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Introduction

(This introduction is not part of ANSI N42.20-2003, American National Standard Performance Criteria for Active Personnel Radiation Monitors.)

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.

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

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American National Standard Performance Criteria for Active Personnel Radiation Monitors

1. Overview

1.1 Purpose

The purpose of this standard is to specify performance and design criteria for personal electronic monitors used for the determination of personal dose equivalent, or dose equivalent rate from external sources, of radiation. It is necessary to standardize the performance and design of devices used for this important purpose. Recent developments in this area of instrumentation have necessitated the revision of ANSI N42.20-1995 for these devices. This standard should be used in conjunction with ANSI N42.17a-2003.[1]

1.2 Scope

This standard applies to the following types of active electronic devices that are worn on the trunk of the body for the purpose of measuring the personal dose equivalent, or dose equivalent rate from external sources, of radiation. The types of dosimeters, include those designed for measuring, are the following:

Type 1—X, gamma, and high energy beta radiations

Type 2—Neutron radiation

Type 3—X, gamma, high energy beta, and neutron radiations (i.e., total dose)

The standard specifies the design and performance criteria for the personal electronic dose monitors and, if supplied, the associated readout system. It applies to devices used for the measurement of personal dose equivalent (rate) from photon radiations (X-rays and gamma rays) of energies 50 keV to 1.5 MeV, beta radiation of maximum energies greater than 500 keV, and neutron radiation from thermal energies to approximately 15 MeV.

This standard does not include instruments referred to as *chirpers,* which are described in ANSI N13.27-1981. This standard does not specify methods for the proficiency testing and accreditation of dosimetry systems. The standard addresses only the radiation detection portions of instruments with telemetric capability. It also does not address passive devices such as thermoluminescent dosimeters, photographic film dosimeters, or quartz fiber electroscope dosimeters. This standard specifies the following items for active personal electronic dosimeters: required general characteristics; general testing procedures; radiation

[1]Information on references can be found in Clause 2.

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characteristics; and electrical, mechanical, safety, and environmental characteristics. The standard specifies the criteria for validating the accuracy of stored dosimetry information. This standard should be used for the evaluation of active personal electronic dosimeters as part of a type testing program or a qualification of the devices for purchase and subsequent use in a radiation protection program. The proficiency testing or accreditation of these devices is covered in related standards developed by Accredited Standards Committee (ASC) N13.

1.3 Relationship to international standards

This standard is consistent with standards being developed by IEC TC45/SC45B. In addition to ANSI definitions, it utilizes definitions of IEC 60050-394:1995 [B1][2] and ISO standards on reference radiations, but it does not use the ICRU operational quantities given in IEC 60050-394:1995, because they have not yet been adopted in the United States.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI N13.11-2001, American National Standard Personnel Dosimetry Performance—Criteria for Testing.[3]

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

ANSI N42.17a-2003, American National Standard Performance Specifications for Health Physics Instrumentation—Portable Instrumentation for Use in Normal Environmental Conditions.

ANSI N42.17c-1989, American National Standard Performance Specifications for Health Physics Instrumentation—Portable Instrumentation for Use in Extreme Environmental Conditions.

ANSI N319-1976 (Reaff 1984), American National Standard for Personnel Neutron Dosimeters/Neutron Energies Less than 20 MeV).[4]

ANSI N323-1978 (Reaff 1993), American National Standard for Radiation Protection Instrumentation Test and Calibration.

ICRU Report 33-1980, Radiation quantities and units.[5]

ICRU Report 51-1993, Quantities and Units in Radiation Protection Dosimetry.

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

[3]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/).

[4]ANSI N319-1976 has been withdrawn; however, copies can be obtained from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

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

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ISO 4037-1:1996, X and Gamma Reference Radiation for Calibrating Dosemeters and Doserate Meters and for Determining Their Response as a Function of Photon Energy—Part 1: Radiation Characteristics and Production Methods.[6]

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

ISO 4037-3:1999, X and Gamma Reference Radiation for Calibrating Dosemeters and Doserate 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.

ISO 6980:1996, Reference Beta Radiations for Calibrating Dosemeters and Doserate Meters and for Determining Their Response as a Function of Beta-Radiation Energy.

ISO 8529:1989, Neutron Reference Radiations for Calibrating Neutron-Measuring Devices Used for Radiation Protection Purposes and for Determining Their Response as a Function of Neutron Energy.

NIST Special Publication 250-1989, Calibration Services User's Guide.[7]

3. Definitions

For the purpose of this standard, the following definitions apply. When the word *tissue* is used in this standard, the specification given in ICRU Report 33-1980 is implied.

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

3.2 accredited testing laboratory: A testing laboratory that has been accredited by an authoritative body with respect to its qualifications to perform verification tests on the type of instruments covered by this standard, ANSI N42.20-2003.

3.3 accuracy: The degree of agreement of the observed value with the conventionally true value of the quantity being measured. This degree of agreement can be quantified by computing the difference between the indicated value of a quantity and the correct (conventionally true) value of the quantity at the point of measurement. In the case of dose equivalent, it is expressed as $H_i - H_t$, where H_i is the indicated value and H_t is the conventionally true value.

NOTE—This definition corresponds to Error of Indication as given in several standards.

3.4 adjust: To alter the reading of an instrument by means of a variable (hardware or software) control.

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

3.6 angular dependence: The dependence of the response of an instrument upon the direction of the incident radiation.

[6]ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iso.ch/). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[7]NIST publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402-9325 (http://www.gpo.gov).

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3.7 conventionally true value: The best estimate of the value determined by a primary or secondary standard or by a reference instrument that has been calibrated against a primary or secondary standard.

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

$$H = DQ$$

The shallow and deep dose equivalents, H_s and H_d, are the dose equivalents at depths in tissue of 0.07 mm and 10.0 mm, respectively.

The SI unit of dose equivalent has been given the special name of sievert (Sv).

1 Sv = 1 J/kg

NOTE—For photon and beta radiation, Q may be taken as equal to unity for external radiations.

3.9 dose equivalent rate: The quotient ($\dot{H}$) of dH by dt, where dH is the increment of dose equivalent in the time interval dt, as shown in the following equation:

$$\dot{H} = dH / dt$$

3.10 effective range of measurement: The range of values of the quantity to be measured over which the performance of a dosimeter meets the requirements of this standard, ANSI N42.20-2003.

3.11 exposure to dose equivalent conversion factor: The numerical quantity that relates the exposure (or air kerma) in air to the dose equivalent at a specified depth in tissue.

3.12 fluence to dose equivalent conversion factor: The numerical quantity that relates the neutron fluence to the dose equivalent at a specified depth in tissue.

3.13 point of measurement: The place at which the conventionally true values are determined and at which the reference point of the monitor is placed for test purposes.

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

3.15 reference phantom: A 300 mm × 300 mm × 150 mm block of polymethylmethacrylate (PMMA). This phantom follows the recommendations of the ICRU and the ISO for a simplified practical phantom for the calibration of dosimeters.

NOTE—The conversion factors for the same-sized phantom constructed of ICRU tissue should be used for evaluating the dose equivalent.

3.16 reference point of an instrument: A physical mark, or marks, on the outside of an instrument used to position it at a point where the conventionally true value of a quantity to be measured is known.

3.17 relative error of indication: The relative error of indication, I, is the quotient of the error of indication of a measured quantity by the conventionally true of that measured quantity. It may be expressed as a percentage, for example, as shown in the following equation:

$$I = \left(\frac{H_i - H_t}{H_t}\right) \times 100\%$$

3.18 response: For a dosimeter, the indication (R), produced as a result of some influence quantity.

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3.19 shallow and deep dose equivalent: The shallow and deep dose equivalents, H_s and H_d, are the dose equivalents at the depths in tissue of 0.07 mm and 10.0 mm, respectively.

4. General testing information

The performance tests that may be used for evaluating dosimeters fall into several categories, depending upon the intended purpose. The categories are defined in 4.1, 4.2, 4.3, and 4.4, along with the applicable purposes. Not all of the tests described herein are mandatory, but such tests as are carried out shall be performed in accordance with the procedures described in this standard.

4.1 Type test

A type test is performed to determine whether a particular design of instrument will meet all of the requirements specified in this standard. It is intended that a comprehensive type test would be performed to ensure that an instrument is acceptable for use in a particular application. If any aspect of the design of this instrument were to be changed, it would have to undergo another qualifying type test.

4.2 Performance test

A performance test makes use of a representative sample of instruments. The performance of this sample is tested against established criteria for performance in all relevant specifications given in this standard. Evaluation of the performance of a sample group of instruments results in either passing or failing the performance test based on the performance criteria.

4.3 Acceptance test

An acceptance test is performed to verify that a group of instruments conforms to the technical specifications required for use. This test is performed subsequent to the purchase of instruments, but before they are put to use.

4.4 Reference conditions and standard test conditions

The required standard conditions for environmental quantities, such as temperature and pressure as well as those for other quantities that may influence the performance of instruments, are given in Clause 5 and Clause 6. Acceptable testing ranges for these quantities are given in Table 1 and shall be met, except where the effect of the condition or quantity itself is being tested.

NOTE—Environmental quantities, such as temperature and humidity, are referred to as *influence quantities* in publications of IEC TC45 and its committees.

5. General performance requirements

5.1 Mechanical requirements

The mechanical design specifications ensure that only instruments designed for the specific purposes outlined in the scope of this standard are tested.

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5.1.1 Size

The overall dimensions of the instruments, excluding any clip or retaining device, should not exceed the following dimensions:

Type 1—15 cm in length, 8 cm in width, and 3 cm in thickness

Type 2—20 cm in length, 10 cm in width, and 5 cm in thickness

Type 3—20 cm in length, 10 cm in width, and 5 cm in thickness

Table 1—Reference and standard test conditions

Quantity	Reference value or acceptable range
Ambient temperature range	20 °C to 24 °C
Reference temperature	22 °C
Ambient relative humidity range	50% to 75%
Reference relative humidity	65%
Atmospheric pressure range	70 kPa to 106 kPa
Reference atmospheric pressure	101.3 kPa
Stabilization time	≤ 10 min
Line voltage stability[a]	±1%
Line frequency range[a]	60 Hz ± 0.5 Hz
AC power supply waveform[a]	Sinusoidal, with total harmonic distortion ≤ 5%
Background ambient dose equivalent rate	≤ 0.25 μSv h^{-1} (25 μrem h^{-1})
Ambient nonionizing electromagnetic field	Negligible
Ambient magnetic induction	Negligible
Instrumental controls	Set up for normal operation
Radioactive contamination	Negligible
Reference point	Effective center as marked
Reference photon radiation	^{137}Cs
Reference beta radiation	$^{90}Sr/^{90}Y$
Reference neutron radiation	^{252}Cf or ^{241}Am-Be
Reference phantom	300 mm × 300 mm × 150 mm PMMA

[a]Applicable only to ac-powered instruments or readers.

5.1.2 Mass

The mass of the instruments should not exceed the following:

Type 1—200 g

Type 2—300 g

Type 3—400 g

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5.1.3 Case construction

The instrument case should be smooth, rigid, shock resistant, and dust and moisture resistant. Means shall be provided to attach the instrument to clothing (e.g., a strong clip, ring, or a lanyard) with attention given to the necessary orientation of the detector, alarms, and indicators.

5.1.4 Reference point marking

The instrument case shall have markings indicating the position of the effective center of detection on both the front (or back) and side of the instrument. The reference orientation with respect to the wearer shall also be marked on the instrument.

5.1.5 Resistance to contamination

The instrument case shall be constructed of materials that are easily decontaminated.

5.2 Electrical and electronic requirements

The electrical and electronic specifications of instruments or readers are given in 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.6, and 5.2.7.

5.2.1 Scale indication

The scale indication for direct reading monitors shall be digital and shall be shown in units of dose equivalent and/or dose equivalent rate. The display shall be clearly visible by the wearer under conditions of expected use.

5.2.2 Dose equivalent and dose equivalent rate ranges

For most applications, the dose equivalents are expected to be as follows:

Type 1 and *Type 2*—From 1 μSv to 1 Sv (0.1 mrem to 100 rem)

Type 3—From 10 μSv to 1 Sv (1 mrem to 100 rem)

Dose equivalent rates to be measured are expected to be as follows:

Type 1 and *Type 2*—From 10 μSv h^{-1} to 1 Sv h^{-1} (1 mrem h^{-1} to 100 rem h^{-1})

Type 3—From 10 μSv h^{-1} to 0.1 Sv h^{-1} (1 mrem h^{-1} to 10 rem h^{-1})

5.2.3 Effective range of measurement or indication

The effective range of measurement shall not be less than from the first non-zero indication in the second least significant digit up to the maximum indication on each range. As an example, for a display with a maximum indication of 199.9, the effective range must extend from 1.0 to 199.9.

Where more than one detector is used for measurement over the complete range, automatic switching shall be provided between the detectors. The tests of this standard shall be performed for all detectors. Where the instrument has range change facilities, these shall also be automatic.

5.2.4 Switches

Any external switches shall be adequately protected from accidental or unauthorized operation. Operation of any switches shall not interfere with the dose equivalent integrating function of the instrument. Switches should be operable through a plastic bag, if used for contamination control, and with gloved hands.

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5.2.5 Alarms

It shall not be possible to set alarm levels by external switches on the monitor. The alarm levels should either be set by the associated readout system or it should be possible to inhibit unauthorized change of alarm levels by an electronic or mechanical access limiting system. If the dosimeter has multiple alarms, they should be easily differentiated by the user. It shall not be possible for the user to reset the primary dose equivalent alarm.

5.2.5.1 Dose equivalent alarms

Either it shall be possible to set this alarm to any value over the complete effective range of measurement of the monitor or it shall be possible to set the alarm to at least one value in each decade of this range [e.g., 3 μSv, 30 μSv, 0.3, 3, 30, and 300 mSv (0.3, 3, 30, 300 mrem, 3 rem, and 30 rem)].

5.2.5.2 Dose equivalent rate alarms

Either it shall be possible to set this alarm to any value over the complete effective range of measurement of the monitor or it shall be possible to set the alarm to at least one value in each decade of this range [e.g., 3 and 30 μSv h^{-1}, 0.3, 3, 30, and 300 mSv h^{-1} (0.3, 3, 30, 300 mrem h^{-1}, 3 and 30 rem h^{-1})].

5.2.5.3 Alarm output

a) *Location*—The audible and/or visual alarm shall be located so that when the monitor is worn on the body, the alarm can still be heard or seen by the wearer.

b) *Audible alarm*—The frequency should be within the range 1000 Hz to 5000 Hz. Where an intermittent alarm is provided, the signal interval shall not exceed 2 s. When the monitor is worn in the recommended position on the body, the volume at the user's ears shall exceed 85 dB (A). The A-weighted sound level shall not exceed 100 dB (A) at 30 cm from the alarm source. Where ambient noise levels would make this alarm inaudible, a visual signal or ear phones shall be provided.

5.2.5.4 Additional indication

Indication shall be given of operation in conditions in which the accumulation of dose equivalent is not accurate (within the specifications of this standard), e.g., low battery supply, detector failure, and in high dose equivalent rate fields.

5.2.5.5 Pre-setable alarm levels

It shall not be possible to set alarm levels by external switches on the instrument. The alarm levels should either be set by the associated readout system or through the authorized use of an electronic or mechanical access limit system.

5.2.6 Batteries

Facilities shall be provided for testing the battery under maximum load during use. In addition, indication shall be provided that at least 8 h of operational life is available at about 0.1 mSv h^{-1} (10 mrem h^{-1}) under normal conditions; this includes 1 min of alarm operation. Provision shall be made for indicating when the battery condition is no longer adequate for the performance of the instrument to meet the requirements of this standard. Primary batteries may be connected in any desired manner; the correct polarity shall be clearly indicated on the instrument by the manufacturer.

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5.2.6.1 Primary battery requirements

a) When power is supplied by primary batteries, the capacity of these batteries shall be such that, after 40 h of intermittent operation under standard test conditions, the response of the instrument shall meet the requirements of 5.3.9. The instrument shall meet this specification in fields of 0.01 to 0.1 mSv h^{-1} (1 to 10 mrem h^{-1}).

NOTE—40 h of intermittent operation means 8 h of continuous use followed by 16 h with the instrument's power switched off for 5 consecutive days.

b) Immediately after new batteries are installed, the instrument shall be capable of operating for at least 15 min with the alarm sounding and with the visual alarm displayed.

c) The primary batteries shall not be easily removable without the use of a special tool or method.

5.2.6.2 Secondary battery requirements

These requirements shall be separately tested for photon radiation and neutron radiation depending upon the type of the instrument.

a) When power is supplied by secondary batteries, the capacity of these batteries shall be such that after at least 12 h of continuous use, the response of the monitor shall not change by more than ±10%, with other functions also remaining within specifications. The instrument shall meet this specification in radiation fields of 0.01 to 0.1 mSv h^{-1} (1 to 10 mrem h^{-1}).

b) Immediately upon recharge, the monitor shall be capable of operating for at least 15 min with the alarm sounding and with the visual alarm displayed. It shall be possible to fully recharge the batteries within 12 h.

5.2.7 Readers

If a separate reader system is used to record and store dose equivalent values measured by the electronic personal dosimeter, it shall be verified to perform the transfer of data accurately with a change of no *more* than plus or minus one digit in the least significant position.

5.3 Radiological requirements

5.3.1 Nature of tests

Unless otherwise specified in the individual clauses, all the tests enumerated in this standard are to be considered as type tests. Certain parts of tests may be considered as acceptance tests decided upon by the user.

5.3.2 Reference conditions and standard test conditions

Reference conditions are given in Table 1. Except where otherwise specified, the tests in this standard shall be carried out under standard test conditions given in Table 1. For those tests not carried out under standard test conditions, the values of temperature, pressure, and relative humidity at the time of test shall be stated and the appropriate corrections made to give the response under reference conditions.

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

5.3.3 Position of instrument for purposes of tests

For all tests involving the use of radiation, the reference point of the instrument shall be placed at the point where the conventionally true value of the quantity to be measured is known and in the orientation with

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respect to the direction of the radiation field as indicated by the manufacturer. This shall not be required for tests of variation of response with angle of incidence.

5.3.4 Accuracy

For the purpose of this test, the conventionally true value of the dose equivalent or dose equivalent rate at the point of test shall be known with an uncertainty of better than ±10%. The tests shall be performed with the appropriate sources selected from Table 1, and the instruments shall be irradiated on the reference phantom. In the event that the full range of dose equivalent dates is not available from a single source of a particular radiation, it is permissible to use several sources with intensities that produce dose equivalent ranges that overlap. For the case of neutron instrument tests, it is permissible to substitute sources other than those specified in Table 1, provided that the response is normalized to that from the sources specified in Table 1.

Where possible, dose equivalent rates of < 1 mSv h^{-1} should be used for determining the accuracy. If this is not possible for practical reasons (e.g., the exposure times would be too long), then corrections for nonlinearity at the higher dose equivalent rates shall be applied.

5.3.5 Low dose equivalent rates

For the measurement of low dose equivalent rates, it is necessary to take account of the contribution of background radiation to the dose equivalent rate at the point of test as well as any inherent effects (electronic noise or inherent radioactivity). It is advisable to only use components with a total inherent contribution corresponding to lower than 1 μSv h^{-1} (0.1 mrem h^{-1}).

5.3.6 Statistical fluctuations

For any test involving the use of radiation, if the magnitude of the statistical fluctuations of the indication arising from the random nature of radiation alone is a significant fraction of the variation of the indication permitted in the test, then sufficient readings shall be taken to ensure that the mean value of such readings may be estimated with sufficient accuracy to determine whether the requirements for the characteristic under test are met.

5.3.7 Reference radiations

Unless otherwise specified in the individual methods of test, all tests involving the use of radiation should be carried out with the specified type of radiation in Table 1. The nature, construction, and conditions of use of the reference radiation sources shall be in accordance with the recommendations in ISO 4037-1:1996, ISO 4037-2:1997, ISO 4037-3:1999, ISO 6980:1996, and ISO 8529:1989 (or NIST Special Publication 250-1989, where appropriate).

5.3.8 Reference gamma and neutron radiation

The reference gamma radiation shall be that provided by the nuclide ^{137}Cs. ^{60}Co sources may also be used, but in this case it will be necessary to correct the measurements to the response from ^{137}Cs.

5.3.9 Radiation performance requirements

Under standard test conditions, with the calibration controls adjusted according to the manufacturer's instructions, the relative error of indication of the instrument shall not exceed ±15% over the whole effective range of dose equivalent measurement and shall not exceed ±20% over the whole effective range of dose equivalent rate measurement. For the lowest decade or scale of dose equivalent rate, ±30% shall not be exceeded. These requirements are applicable for photon beta and neutron radiations.

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5.3.10 Response time requirements for dose equivalent rate monitors

When the instrument is subjected to a step increase or decrease in dose equivalent rate, the readout shall indicate the new dose equivalent rate with a relative error of indication of less than ±20% within 5 s. This shall apply for dose equivalent rates greater than 10 μSv h^{-1} (1 mrem h^{-1}).

5.3.11 Accuracy of alarm to set value requirements for dose equivalent rate monitors

When the instrument is subjected to dose equivalent rates of 0.80 of the dose equivalent rate alarm set point for ten min, the alarm shall not be activated for more than 10% of the period of the test. Similarly, at a dose equivalent rate of 1.2 of the alarm level set, the alarm shall be activated at 90% of the period of test. When the instrument is subjected to dose equivalent rates of 1.20 of the dose equivalent rate alarm set point, the alarm should actuate within 5 s or within a time such that the product of this time and the dose equivalent rate of the alarm point is less than 10 μSv (1 mrem).

At least two tests shall be carried out, one with the alarm set to near the maximum range of indication and one with the alarm set to near the maximum value of the second least significant decade.

5.3.12 Requirements for dose equivalent monitors

When the instrument is subjected to a dose of 0.85 of the dose equivalent alarm set point, no alarm shall be given, and when the monitor is subjected to a dose equivalent of 1.15 of the dose equivalent alarm set point, the alarm shall sound.

At least two tests shall be carried out, one for an alarm set point equal to, or greater than, 85 rem and one near the maximum value of the second least significant decade.

5.3.13 Variation of response with radiation energy requirements—photon radiation

The response, in the calibration direction, to incident radiation of energy between 50 keV and 1.5 MeV shall not differ by more than ±30% from the response to the ^{137}Cs (662 keV) reference gamma radiation source.

5.3.14 Variation of response with angle of incidence of radiation requirements—photon radiation

For two planes, one horizontal and one vertical through the front face of the monitor (see Figure B.1), the ratio of the monitor reading at α angle relative to the reading at $\alpha = 0°$ for angles from 0° to ±75° shall be within ±20% of the ratios given in Table B.1 for ^{137}Cs and within ±50% of the ratios for ^{241}Am (or 60 keV filtered X radiation). The manufacturer shall state the response at 90°.

5.3.15 Retention of dose equivalent reading

This subclause applies to instruments that measure dose equivalent; that is, it does not apply to dose equivalent rate measurements.

5.3.15.1 Requirements

a) At the end of any exposure period, the reading of the instrument and that indicated by any associated readout system (if supplied) should not change by more than ±2% or a single change in the least significant digit, whichever is the greatest, over the next 8 h.

b) After 24 h from the loss or interruption of the principal voltage supply, the integrated dose equivalent measured by the monitor, and from any associated readout system, prior to this loss or

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interruption shall not change by more than ±5%, or 1 mrem (whichever is larger) upon replacement of the principal voltage supply.

5.3.16 Response to beta radiations requirements

The instrument reading for incident beta radiation with average energy greater than 2.0 MeV should not differ by more than ±50% from the conventionally true value of H_s.

5.3.17 Response of a photon instrument to neutron radiation

The instrument reading for instruments designed to measure neutrons should not differ by more than ±50% from the conventionally true value of H_d for neutron sources indicated in Table 1.

5.3.17.1 Requirements

The response to neutrons shall be less than 5% of the delivered dose equivalent.

5.3.18 Dose equivalent rate dependence requirements

The response of the instrument shall be such that its dose equivalent relative error of indication remains within ±20% for all dose equivalent rates up to 1 Sv h^{-1} (100 rem h^{-1}).

5.3.19 Overload characteristics requirements

For dose equivalent (rates) greater than that corresponding to the maximum value of the upper decade and up to two times the maximum indication, the instrument shall be “off-scale” at the higher end of the scale and shall remain so while in that radiation field. The manufacturer shall state the time taken for monitors that indicate dose equivalent rate to return to the appropriate “on-scale” dose equivalent rate reading following the irradiation to this overexposure. For the dose equivalent irradiation, the indication shall remain “off-scale” upon removal from the radiation field. For dose equivalent monitors where the dose equivalent rate during integration exceeds the measurable rate, an overload condition shall be indicated and remain until reset. The measurable rates are those for which the requirements of this subclause are met; the manufacturer shall state the upper limits of such rates.

5.4 Environmental requirements

5.4.1 Ambient temperature requirements include operational frequency range specified

a) Over the ranges of temperature specified in Table 1, the indication shall remain within the limits specified in that table.

b) The mean instrument response shall not vary by more than ±15% from a set of reference readings taken at a temperature of 20 °C when the monitor is taken from 20 °C to 50 °C and to –10 °C, each in less than 5 min.

The mean instrument response shall vary not more than ±15% from a set of reference readings taken at a temperature of 50 °C or –10 °C when the monitor is taken from either one of those temperatures to one of 20 °C.

5.4.2 Relative humidity requirements

This test shall be performed separately for photon beta radiation and for neutron radiation where applicable. The variation in the indication due to the effect of relative humidity from 40% to 90% shall be within ±10%.

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5.4.3 Atmospheric pressure

The influence of atmospheric pressure is, in general, only significant for an unsealed detector using air as the detecting medium. In this case, the atmospheric pressure at which all tests are performed shall be stated, and the effects of variations in atmospheric pressure shall be stated by the manufacturer. Representative tests at other atmospheric pressures shall be performed if required.

5.4.4 Sealing

The mean instrument response shall not vary more that ±15% from the mean of a set of reference readings, after being subjected to water spray in accordance with 6.4.3.

5.4.5 External electromagnetic fields

Unless special precautions are taken in the design of an instrument, it may be rendered inoperative or give incorrect indication of dose equivalent (rate) in the presence of external electromagnetic fields, particularly radio-frequency fields.

5.4.5.1 Requirements

5.4.5.1.1 General

If the indication of a monitor may be influenced by the presence of external electromagnetic fields, a warning of this effect shall be given by the manufacturer and this shall be stated in the operation manual. If a manufacturer claims that a monitor is insensitive to electromagnetic fields, the range of frequencies and types of electromagnetic radiation in which the monitor has been tested shall be stated by the manufacturer, together with the maximum intensity used.

5.4.5.1.2 Specific

All tests should be done in accordance with the specifications of IEC 61000-4-1:2000 [B4].

6. Performance tests

The following subclauses describe the specific tests to be performed as part of type tests, performance tests, or acceptance tests. A subset of these tests should be used for periodic performance testing.

6.1 Mechanical tests

These tests are intended to determine the effect of mechanical manipulation of the instrument upon its current, or stored, reading of dose equivalent or dose rate equivalent.

6.1.1 Drop test

The instrument shall be exposed to a dose equivalent of 1 μSv (100 mrem) of photons, beta particles or neutrons (or all three radiations, depending upon the intended use). The dose equivalent shall be deep dose equivalent for photons or neutrons, and shallow dose equivalent for beta particles, using the reference sources given in Table 1. The instrument shall then be dropped from a height of 1.5 m onto a hard wood surface. The displayed reading of dose equivalent or dose equivalent rate, along with the stored readings of either of these values, shall not change by more than ±5% after the unit has been dropped on each of its six surfaces. There shall be no visible external damage to the instrument, and all control functions are to be verified to be correctly operative. A simplified accuracy and linearity check using the reference radiations given

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in Table 1 shall indicate satisfactory performance after all drops have been performed. The accuracy shall be within ±10% of the reference value, and linearity shall be within ±10% at dose equivalent readings of 20%, 50%, and 80% of full range.

6.1.2 Shock test

The instrument shall be exposed to a dose equivalent of 1 μSv (100 mrem) of photons, beta particles, or neutrons (or all three radiations, depending upon the intended use). The dose equivalent shall be deep dose equivalent for photons or neutrons, and shallow dose equivalent for beta particles, using the reference sources given in Table 1. The instrument shall be subjected to harmonic loadings of at least 2 g_n for 15 min, in the frequency range of 10 Hz to 30 Hz, in each of three orthogonal directions. The displayed reading as well as any stored readings shall not have changed by more than ±5%. A simplified accuracy and linearity test, as described in 6.1.1, shall be performed to verify no change greater than ±10%.

6.2 Electrical and electronic tests

6.2.1 Battery lifetime (primary and secondary batteries)

New primary batteries or fully charged secondary batteries of the type indicated by the manufacturer shall be used for each of these tests.

a) Expose the monitor to a radiation field sufficient to provide a suitable indication on the assembly. Leave the monitor working in this field for a period or periods given in 5.2.6, as appropriate, and note the reading at the end of each period. Each reading shall conform with the requirements of 5.2.6, as appropriate.

b) General requirements shall be tested for 8 h of operation (see 5.2.6). Expose the monitor to a source of radiation until the additional indication that 8 h operational life is available. The instrument should then be zeroed using the appropriate device (e.g., readout system). After 8 h of continuous operation under standard test conditions, but exposed to a dose equivalent rate of about 0.1 μSv h^{-1} (10 mrem h^{-1}), the monitor's response shall not change by more than ±15%.

6.2.2 Electromagnetic interference

a) The instrument shall be placed within a magnetic field generator coil producing a field of 800 Am^{-1}, parallel to the radiation beam. An appropriate source selected from Table 1 will be used to generate an indication that shows minimal statistical fluctuation. Over a period of 10 min, the coil shall be energized for 15 s, and this shall be repeated every 2 min. The indication shall not have changed by more than ±20%.

b) Electrostatic interference shall be tested by placing the instrument between two plates energized to generate a dc field of 5000 V m^{-1}. The requirements of 6.2.2 shall be met.

6.2.3 Alarm acoustic intensity

The instrument's alarm shall be activated with an appropriate radiation source (that may be placed as close to the instrument as practical), and the A-weighted sound level at a distance of 30 cm shall be measured and compared to the specifications given in 5.2.5.1, 5.2.5.2, 5.2.5.3, 5.2.5.4, and 5.2.5.5.

6.2.4 Reader data transfer reliability

The instrument shall be irradiated to dose equivalent values of 10%, 50%, and 80% of the full instrument range using an appropriate source from Table 1. After each irradiation, the instrument shall be used to transfer its data to the appropriate reader or data storage device. The consistency between the instrument's

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indication and the value recorded by the reader shall be no more than plus or minus one least significant digit.

6.3 Radiological tests

The reference radiations to be used for the tests described in this subclause are to be selected from those listed in Table 1. The radiations used must be appropriate for the intended use of the instrument. Unless otherwise stated, radiological tests are to be performed with the instrument mounted on the surface of the reference phantom described in Table 1.

6.3.1 Accuracy

For purposes of this test, the conventional true value of the personal dose equivalent, or rate, at the point of test shall be known with an uncertainty of better than ±10%. The tests shall be performed with sources of ^{137}Cs irradiating the monitor on an appropriate phantom (see Annex B) in the calibration direction.

NOTE—Shielding of sources shall meet requirements of appropriate ISO or NIST standards.

In the case where multiple sources are used, the relative activities of the sources used shall be such that the useful range of dose equivalent (rates) obtainable from each source at the point of test (by alteration of the distance between the source and the detector of the monitor) overlaps the useful range of dose equivalent (rates) obtainable from at least one other of the sources used.

Where possible, dose equivalent rates of < 1 mSv h^{-1} (<100 mrem h^{-1}) should be used for determining the relative error of indication for dose equivalent measuring monitors. Where for practical reasons this is not possible, e.g., exposure times would be too long, corrections for nonlinearity at these higher dose equivalent (rates) used shall be applied.

6.3.2 Precision

The instrument shall be exposed to an appropriate source selected from Table 1 to a dose equivalent of 10%, 50%, and 80% of the full scale of the instrument, and then to a maximum of 100 rem. At each of these dose equivalent levels, 10 replicate exposures shall be conducted and the variance shall be calculated. The variance at each level shall not exceed ±5%.

6.3.3 Linearity

Determine the relative error of indication of the instrument at 80% of each decade when the monitor is exposed to a reference source at approximately the following dose equivalent rates: 10 and 100 mSv h^{-1}, and 1 Sv h^{-1} (1, 10, and 100 rem h^{-1}).

Since at the lower dose equivalents the exposure times will be too short for the higher rates, while at high dose equivalents the exposure times will be too long for the lower rates, these tests should exclude any exposures involving times of less than 3 s or exceeding 10 h.

However, since the instruments may be worn operationally in areas of transient high dose equivalent rates the monitor shall be tested for short exposure under these conditions. The monitor shall be exposed for 5 s at approximately 1 Sv h^{-1} (100 rem h^{-1}), and it shall then read within ±20% of the calculated dose equivalent for 5 s irradiation.

6.3.4 Detection threshold

The instrument shall be exposed to appropriate sources selected from Table 1 at dose equivalents near the low end of the range of the instrument. Dose equivalents of 10%, 5%, and 1% (with additional increments as

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necessary to complete the test) of the lowest range shall be measured, and the variance for 10 replicate readings evaluated. The detection threshold will be stated as the dose equivalent at which the variance is greater than ±20%.

6.3.5 Energy response

For this test, the instrument shall be placed on the PMMA phantom. The following energies selected from the list of photon reference radiations specified by NIST Special Publication 250-1989 shall be used:

a) Filtered X-rays with mean or effective energies of approximately 48, 60 (or $_{241}$Am), 87, 109, 148, and 211 keV

b) Gamma radiations from ^{137}Cs (662 keV) and ^{60}Co (1.17 and 1.33 MeV)

The energy response of instruments responding to beta particles or neutrons should be determined by methods decided by the user.

In principle, it is desirable that these tests be performed at the same dose equivalent (rate) for each radiation energy. In practice, this may not be possible, in which case the indicated dose equivalent (rate) at each radiation energy shall be corrected for the relative error of indication (interpolated if necessary) at that indicated dose equivalent (rate) for the reference gamma radiation source.

6.3.6 Angular response

The test shall be performed for both the photon radiations from ^{241}Am (59.5 keV) (or 60 keV filtered X-radiation) and from ^{137}Cs (662 keV). The nature, construction, and conditions of use of the radiation sources should be in accordance with the recommendations in NIST Special Publication 250-1989, ISO 4037-1:1996, ISO 4037-2:1997, or ISO 4037-3:1999.

Place the monitor on the PMMA phantom in its normal position of use, with the source of radiation in the reference direction for calibration purposes specified by the manufacturer. The reading in this position shall be noted. For two planes, horizontal and vertical, the monitor and the phantom shall be rotated to angles of ±15°, ±30°, ±45°, ±60°, ±75°, and ±90°. The readings shall be taken at all these orientations and the ratios at these angles relative to 0° calculated. The ratios for ±90° shall be stated by the manufacturer.

6.3.7 Overrange response

The instrument shall be irradiated to a dose equivalent of two times the dose equivalents given in 5.2.2. The indication of the instrument shall remain at the maximum of the range, and an overload indication shall be displayed.

The instrument shall be irradiated, for example for 10 min, to a dose equivalent rate of two times the dose equivalent rates given in 5.2.2. The indication of the instrument shall remain at the maximum of the range and an overload indication shall be displayed.

6.3.8 Mixed field response

If the instrument is intended for use only in radiation fields specified by the manufacturer, it shall be tested for the influence of other radiations upon the reading. A source that is not measured by the instrument is to be selected. Appropriate sources are to be selected from Table 1 and used to irradiate the instrument to a dose equivalent of 10 μSv (1 rem). The result of this irradiation is not to result in a reading of more than 2.5% of full scale.

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6.4 Environmental conditions tests

It is necessary to demonstrate that variations in environmental conditions to which the instrument is exposed will not affect the operation or the retention of accurate readings of dose equivalent or dose equivalent rate.

6.4.1 Temperature

For this test, the instrument shall be exposed to a reference photon source providing a sufficient indication under standard test conditions for the test to be carried out.

a) Then the temperature shall be maintained at each of its extreme values for at least 4 h, and the indication of the instrument measured during the last 30 min of this period. The limits of variation of indication shall be within the values given in Table 2.

b) The instrument shall be placed in a temperature of 20 °C ± 2 °C and allowed to stabilize for a minimum of 60 min. The instrument shall be exposed in a reproducible geometry to a photon source of sufficient intensity to minimize the effect of statistical fluctuations of the readings and to produce a response of approximately the middle of the second least significant decade. The mean monitor reading shall be determined after a sufficient number of readings are taken to reduce statistical fluctuations. The instrument and the source shall be removed from this environment and placed directly into an environmental chamber such that the same exposure geometry is established and the temperature near the monitor is at least 50 °C. This procedure shall be performed in less than 5 min. The mean reading shall be determined then and every 15 min for 2 h. If the monitor does not fail the test within the first hour, data does not need to be taken during the second hour; however, the instrument should remain in this environment during the period to reach temperature stabilization. The instrument and source shall be removed from the environmental chamber and returned to the first environment such that the same exposure geometry is established and the temperature near the monitor is 20 °C ± 2 °C. This procedure shall be performed in less than 5 min. The mean instrument reading shall be determined then and every 15 min for 2 h. If the instrument does not fail within the first hour, data does not need to be taken during the second hour; however, the instrument should remain in this environment during the period to reach temperature stabilization.

The test shall be repeated with the temperature inside the environmental chamber near the monitor at –10 °C or lower.

6.4.2 Humidity

The test shall be carried out at a single temperature of 35 °C (± 2 °C) using an environmental chamber. For this test, the instrument shall be exposed to the reference source in contact with the monitor, providing a sufficient indication under standard test conditions for the test to be carried out.

Then the humidity shall be maintained at each of its extreme values for at least 4 h and the indication of the instrument noted during the last 30 min of this period. The permitted variation of ±10% in the indication is additional to the permitted variations due to temperature alone.

6.4.3 Moisture resistance

The instrument shall be exposed in a reproducible geometry to a source of ionizing radiation (chosen from Table 1) of sufficient intensity to minimize the effect of the statistical fluctuations of the instrument and to produce a response of approximately mid-scale or mid-decade. The mean instrument reading shall be determined after a sufficient number of readings are taken. The instrument shall then be exposed for 2 min to a fine water spray at a flow rate of approximately 4 L/min. The spray nozzle should be located approximately 2 m from the instrument. The instrument shall respond to the presence of radiation throughout the test and after the test. The temperature of the water and the instrument shall be 20 °C ± 5 °C.

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Table 2—Tests performed with variations of influence quantities

Characteristic under test or influence quantity	Range of values of influence quantity	Limits of variation of indication
Relative intrinsic error	Effective range of measurements	Dose equivalent ±15% Dose equivalent rate ±20%
Response time	5 s	< ±20%
Accuracy of alarm levels	All settings	Dose equivalent ±15% Dose equivalent rate ±20%
Radiation energy Photon High-energy beta Neutron	 50 keV to 1.5 MeV E_{max} = 3.5 MeV Thermal to 15 MeV	 ±30% ±50% ±50%
Angle of incidence Photon Neutron	 0° to ±75° 0° to ±75°	 ±30° for ^{137}Cs ±50° for ^{241}Am ±30°
Retention of reading	24 h after loss of power supply	±5%
Dose equivalent rate dependence	Up to 1 Sv h^{-1}	< ±20%
Other ionizing radiation response	At 10 μSv	< 2% full scale
Overload	Two times range maxima	Indication greater than full scale
Power supply voltage Primary batteries Secondary batteries	 > 100 h continuous use > 10 h continuous use	 ±15% ±15%

7. Documentation

7.1 Type-test report

The manufacturer shall make available a report on the type tests performed in accordance with the requirements of this standard.

7.2 Certificate

A certificate shall be provided, containing at least the following information:

a) Manufacturer's name and address
b) Type of instrument, detector, and types of radiation the instrument is intended to measure
c) Range of dose equivalent and dose equivalents rates the instrument is intended to measure
d) Reference point and reference orientation relative to the radiation source used for calibration
e) Location and dimensions of the sensitive volumes of the detectors
f) Areal density (mg/cm^2) of walls or other materials between the source and detector
g) Response as a function of radiation energy for appropriate radiations
h) Response as a function of radiation angle of incidence
i) Results of accuracy, linearity, and lower limit of detection tests
j) Mass and dimensions of instruments

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k) Power supply requirements
l) Results of environmental tests
m) Results of electrical and mechanical tests

7.3 Operation and maintenance manual

An operation and maintenance manual containing at least the following information shall be supplied:

a) Operating instructions and restrictions
b) Schematic electrical diagrams, including spare parts lists and specifications
c) Reader and interface operation
d) Troubleshooting guide

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Annex A

(informative)

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[B2] IEC 60068 (series), Basic environmental testing procedures.

[B3] IEC 60395:1972, Portable X or Gamma Radiation Exposure Rate Meters and Monitors for Use in Radiological Protection.

[B4] IEC 61000-4-1:2000, Electromagnetic Compatibility (EMC)—Part 4-1: Testing and Measurement Techniques—Overview of IEC 61000-4 Series.

[8]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA.

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Annex B

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Angular dependence

For the tests performed with variations of influence quantities (angle of radiation incidence), the expected variation of dosimeter reading with angle of radiation incidence is given in Table B.1. The geometrical arrangement of the dosimeter and the phantom with respect to the angle of radiation incidence, α, is shown in Figure B.1.

Table B.1—Expected angular dependence of reading[a]

Radiation source	15°	30°	45°	60°	75°
^{241}Am	0.99	0.97	0.90	0.77	0.51
^{137}Cs	1.00	1.00	0.98	0.95	0.8

[a]Ratio of reading at indicated angle relative to 0°.

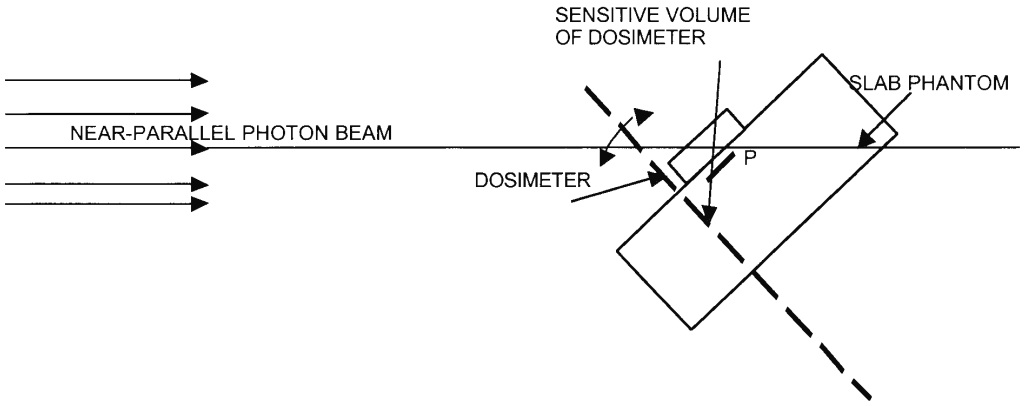


Figure B.1—Arrangement for the calibration of personal dosimeters at angle α

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