



American National Standard
ANSI/HPS N13.11-2009 (R2015)

**Personnel Dosimetry Performance—
Criteria for Testing**

**Approved 13 January 2009
Reaffirmed 12 March 2015**

American National Standards Institute, Inc.



Published by

Health Physics Society
1313 Dolley Madison Blvd.
Suite 402
McLean, VA 22101

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Printed in the United States of America

ANSI/HPS N13.11-2009 (R2015)

This standard was consensus-balloted and approved by the ANSI-accredited HPS N13 Committee on September 9, 2008. At the time of balloting, the HPS N13 Committee had the following membership:

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Foreword

(This foreword is not a part of American National Standard ANSI/HPS N13.11-2009.)

This American National Standard provides a procedure for testing the performance of dosimetry systems (i.e., the hardware, the software, and the processor supplying the services, or in some cases the user of the services) for the purpose of monitoring personnel exposure to ionizing radiation. In 1973, the Conference of Radiation Control Program Directors appointed a task force with state and federal participation. The purpose of this task force was to implement the Conference recommendation for the establishment of a program for testing of personnel dosimetry performance throughout the United States on a continuing basis. After ten years of development and pilot testing, the first standard was issued in 1983 as ANSI N13.11-1983. That standard formed the basis of the Nuclear Regulatory Commission's (NRC) test program administered by the National Voluntary Laboratory Accreditation Program (NVLAP). The Department of Energy (DOE) modified ANSI N13.11-1983 for use at DOE facilities and, in 1986, issued DOE/EH-0027 as the standard that formed the basis of DOE's test program known as the DOE Laboratory Accreditation Program (DOELAP).

By ANSI policy, standards must undergo periodic review and modification if necessary. After extensive review, the first modification of ANSI N13.11-1983 was issued in 1993 as HPS N13.11-1993. The working group for that effort believed that it was not possible to write a useful standard without considering how the standard is applied in the real world. Consequently, the group had hoped to produce a document that would be acceptable to both the DOE and the NRC, but the DOE did not accept it. The third version, HPS N13.11-2001, was developed by a working group that convened in 1996 and worked through 2000. The overarching objective of this group was to produce one standard to suit the needs of both the DOE and the NRC (and the states) for their DOELAP and NVLAP programs. This objective is prudent because it makes sense for the United States to have a single dosimeter performance test program. The group's other objectives were to simplify the standard, to reduce the number of test dosimeters required, and to take no action that would prevent or preclude the use of electronic dosimeters or other future technology. Still, the DOE did not adopt the standard.

The current version, ANSI/HPS N13.11-2009, was developed by a working group convened in 2005 that worked through 2007. This group was made up of people with widely varied backgrounds, including DOELAP and NVLAP assessors; dosimeter vendors; government, military, and national standards laboratories; and the nuclear power industry. The group held eight meetings over a period of three years to create this third revision of the original standard.

At the first meeting of this working group, members and experts from outside the group were invited to make presentations about concerns with the 2001 version of the standard. As a result of these presentations and initial discussions, about a dozen major issues were identified that were considered in the writing of this version of the standard. The following paragraphs describe how the group resolved many of the issues. Some of these items are treated in detail in the appendices.

Historically, N13.11 has been somewhat of a hybrid of a type test and a periodic test. This version can also be generally perceived in that way. Most criticisms of such a hybrid test concern the high cost to test participants. It is suggested that if there were two separate tests (i.e., type and periodic), there would likely be a high "front-end" cost and a lowering of periodic costs. The working group was sensitive to the cost issue and has helped the situation by reducing the number of test categories from six to five. The group endeavored to reduce the number of dosimeters required for testing while making the test comprehensive enough for the needs of both DOELAP and NVLAP.

The six categories in HPS N13.11-2001 have been reduced to five in this standard by combining the two photon categories, thereby embedding mixtures within the photon category. The 58 x-ray beam codes approved for use in HPS N13.11-2001 have been reduced to 33 in this standard. To accommodate the increased complexity of the new photon mixtures category, the number of dosimeters used in this category has been raised from 15 to 21. The narrow-spectrum series (i.e., ^{241}Am , ^{137}Cs , and ^{60}Co), particularly appropriate for DOE facilities, remains as an option in the photon category.

The beta category has been modified to make ^{85}Kr the sole low-energy beta-particle source; ^{204}Tl has been eliminated. While functionally similar, the ^{85}Kr half-life is longer, and its available activities are greater than for ^{204}Tl . In addition, testing with uranium in a slab geometry has been added as a special subcategory.

The performance criteria have been changed to be consistent with ANSI/HPS N13.32-2008. The tolerance equation is now $B^2 + S^2 \leq L^2$, where B is the bias, S is the standard deviation, and L is the tolerance level. The value of L is 0.24 for the accident photon category and 0.3 for all other categories. After much discussion, the performance quotient limit (PQL) introduced in the previous version of the standard was eliminated. The group concluded that the revised pass/fail criteria and other changes rendered the tests sufficiently challenging.

The dose ranges for the accident and non-accident categories have traditionally had a breakpoint at 100 mSv (10 rem). To prevent excessive numbers of dosimeters from being damaged by such high doses, the upper limit of the range for the photon mixture category has been decreased to 50 mSv (5 rem); the group believed that the number better reflected a reasonable upper limit on routine occupational doses. The lower limit of the range for the photon mixture category has been changed to 0.5 mSv (50 mrem) because no single photon personal dose equivalent is allowed to be less than 0.25 mSv (25 mrem). Since the regulatory limit for the shallow dose equivalent is a factor of 10 higher than for deep dose equivalent, the upper limit of the beta and photon/beta mixture categories has been increased to 250 mSv (25 rem). Similarly, the lower limit of the beta category has been raised to 2.5 mSv (250 mrem) and the photon/beta mixture category lower limit for shallow dose equivalent has been raised to 3 mSv (300 mrem). The upper limit of the neutron/photon mixture category remains at 50 mSv (5 rem) for practical irradiation time considerations. The lower limit of 1.5 mSv (150 mrem) remains for the neutron/photon mixture category.

Limits have been placed on the number of dosimeters that can be irradiated in certain dose regions: no more than two dosimeters in a test may be irradiated below twice the lower dose limit, and no more than two may be irradiated above half of the upper dose limit. Because so many dosimeters were being irradiated at non-perpendicular angles under the previous version of the standard, limits have been placed on the number of non-perpendicular irradiations in the photon category. Finally, in the beta/photon category, the shallow dose equivalent:deep dose equivalent ratio has been modified such that the ratio of the photon $H_p(0.07)$ to the beta particle $H_p(0.07)$ is restricted to be in the range of 1:1 to 1:6, inclusive, to better reflect some workplace environments.

The conversion coefficients for photons used in this standard are unchanged from the previous version of the standard. However, after much discussion, the working group decided to change the neutron fluence to personal dose equivalent conversion coefficients to those currently promulgated by the International Organization for Standardization (ISO). Because the ISO coefficients were calculated for a slab phantom making use of the latest alpha and proton stopping power information, such a change results in technical consistency with the coefficients for the other types of radiation used in this standard.

For practical purposes, the polymethyl methacrylate (PMMA) phantom will continue to be used in this standard, but with the addition of a specification for phantom backscatter. Also, the reference dose point (RDP) will continue to be on the phantom surface (i.e., the current NVLAP practice). However, the irradiating laboratory (IL) may adjust the absorbed dose or personal dose equivalent at the sensitive elements of the dosimeter, if the test participant desires it and supplies the distance between the surface of the phantom and the sensitive elements.

Finally, the test schedule has been tightened by requiring that the IL return dosimeters to the test participant within 15 calendar days from the completion of each round of testing. In addition, this standard recommends that the test participant report results within 15 calendar days from receipt of the dosimeters from the IL.

Suggestions for improvement of this standard will be welcome. They should be sent to the Health Physics Society, 1313 Dolley Madison Boulevard, Suite 402, McLean, VA 22101.

American National Standard for Dosimetry – Personnel Dosimetry Performance – Criteria for Testing

1.0 Purpose and Scope

1.1 Purpose

This standard establishes the test conditions and performance criteria for evaluating personnel dosimetry systems.

1.2 Scope

This standard applies to dosimetry systems used to determine personal dose equivalent for occupational conditions and absorbed dose for accident conditions. Tests are conducted under controlled conditions and include irradiation with photons, beta particles, neutrons, and selected mixtures of these radiations. The range of delivered absorbed doses or personal dose equivalents and tolerance levels are based on considerations of radiation protection expressed in current publications of the National Council on Radiation Protection and Measurements (NCRP 1993), the International Commission on Radiation Units and Measurements (ICRU 1992), and the International Commission on Radiological Protection (ICRP 1991, 1997). Organizations should be tested in those categories that best represent the dosimetry services they provide or use. The tests outlined in this standard may be used to test the suppliers of dosimetry services (processors).

The standard integrates angular testing using photon fields incident at various angles to the plane of the dosimeter. Such tests provide the test participant with:

- a method to continuously evaluate long-term changes in dosimeter construction, and
- information for improving absorbed dose or personal dose equivalent estimation under field conditions.

Several dosimetry uses and radiological conditions are outside the scope of this standard because of dosimeter design, limitations of dosimetry systems, and practical considerations of testing equipment and sources. These include:

- thermal neutrons,
- high-energy neutrons ($\bar{E} \geq 3$ MeV), and
- extremity dosimeters (covered in ANSI/HPS N13.32-2008).

The scope of this standard is sufficiently comprehensive that satisfactory performance implies that a dosimetry processor or user is competent to assess personal dose under a broad range of field conditions using the tested dosimetry system for those categories for which they were tested.

2.0 Definitions

Absorbed dose, D : The quotient of $d\bar{E}$ by dm , where $d\bar{E}$ is the mean energy imparted by ionizing radiation to matter of mass dm , thus:

$$D = \frac{d\bar{E}}{dm} \quad (\text{Eq. 1})$$

Unit: J kg^{-1}

Note 1: The special name for the unit of absorbed dose is gray (Gy). The special unit of absorbed dose, rad, is 10^{-2} Gy.

Note 2: The definition of the absorbed dose, D , as a point function, allows the specification of the spatial variations of D as well as the distribution of the absorbed dose in linear energy transfer at the point of interest.

Note 3: Shallow absorbed dose is defined as the absorbed dose at a depth of 0.07 mm in ICRU tissue and is denoted by $D(0.07)$. Deep absorbed dose is defined as the absorbed dose at a depth of 10 mm in ICRU tissue and is denoted by $D(10)$.

Air kerma, K_a : The quotient of dE_{tr} by dm , where dE_{tr} is the sum of the initial kinetic energies of all electrons liberated by photons in a volume element of air of mass dm , thus:

$$K_a = \frac{dE_{tr}}{dm} \quad (\text{Eq. 2})$$

Note: The unit of the air kerma is gray, which has units of joules per kilogram (J kg^{-1})

Average energy, $\bar{E}$: The fluence-weighted average energy of a field of photons, beta-particles, or neutrons calculated as:

$$\bar{E} = \frac{\int_{E_{\min}}^{E_{\max}} N(E)E dE}{\int_{E_{\min}}^{E_{\max}} N(E) dE} \quad (\text{Eq. 3})$$

where $N(E)$ is the fluence with energy between E and $E + dE$, $E_{\max}$ is the maximum energy present in the spectrum, and $E_{\min}$ is the minimum energy considered for the average.

Bias, B : The mean value of the performance quotient, P_i , of a set of dosimeter test results:

$$B \equiv \bar{P} = (1/n) \sum_{i=1}^n P_i \quad (\text{Eq. 4})$$

where the sum is extended over all n values of P_i for a particular test in a given radiation category (or subcategory), and for a particular phantom depth (shallow or deep), and where n is the number of test dosimeters included in the test for that category and depth.

Calibration: The quantitative determination, under a controlled set of standard test conditions, of the reading given by a dosimeter as a function of the value of the quantity to be measured.

Conventional quantity value: The quantity value attributed by agreement to a quantity for a given purpose.

Note 1: The conventional quantity value is the best estimate of the value of the quantity to be measured, determined by a primary standard or a transfer standard that is traceable to a primary standard. Within an organization, the result of a measurement obtained with a secondary standard instrument may be taken as the conventional value of the quantity to be measured.

Note 2: A conventional quantity value is, in general, regarded as being sufficiently close to the true quantity value for the difference to be insignificant for the given purpose.

Conversion coefficient: The quotient of personal dose equivalent, $H_p(d, \alpha)$, by the quantity for which the field is calibrated ("field quantity"), air kerma or fluence, averaged over the field spectrum, thus:

$$\bar{c}_{K, d, \alpha} = \frac{H_p(d, \alpha)}{K_a} \quad \text{for photons} \quad (\text{Eq. 5})$$

$$\bar{c}_\varphi = \frac{H_p(10)}{\varphi_n} \quad \text{for neutrons} \quad (\text{Eq. 6})$$

where for photons d is 0.07 mm in ICRU tissue for the shallow depth and 10 mm for the deep depth, and α is the angle of radiation incidence.

Note 1: The unit of the conversion coefficient is Sv Gy^{-1} (rem rad^{-1}) for photons and Sv m^2 (rem m^2) for neutrons.

Note 2: For the purposes of this standard, photon conversion coefficients for ISO techniques are taken from ICRU (1998) and for the NIST techniques from Soares and Martin (1995). For neutrons, values for the conversion coefficients are taken from ISO (1998).

Note 3: For beta particles, because the field quantity is absorbed dose and the quality factor is unity, the conversion coefficient is unity.

Dosimeter: A device to assess the absorbed dose or personal dose equivalent from ionizing radiation received by a person. The dosimeter consists of radiation-sensitive elements and their surrounding packaging.

Equivalent dose, $H_{T,R}$: The product of $D_{T,R}$ and w_R , where $D_{T,R}$ is the mean absorbed dose in an organ or tissue and w_R is the radiation weighting factor for the radiation incident on the body, thus:

$$H_{T,R} = w_R D_{T,R} \quad (\text{Eq. 7})$$

Note 1: The unit of the equivalent dose is joules per kilogram (J kg^{-1}) with the special name sievert (Sv). The special unit of equivalent dose, rem, is 10^{-2} Sv.

Note 2: For the purposes of this standard, for photon and beta radiation, the radiation weighting factor has the value unity.

Full width at half-maximum, FWHM: The width of a continuum spectrum at half of its maximum value, neglecting any monoenergetic lines.

Half-value layer: The thickness of material that reduces the air kerma of a radiation beam by one half.

Homogeneity coefficient: The ratio of the first and second half-value layers times 100.

ICRU tissue: A tissue-equivalent (TE) material defined in ICRU Report 33 (ICRU 1980) having a density of 1 g cm^{-3} and a composition by mass of 76.2% oxygen, 10.1% hydrogen, 11.1% carbon, and 2.6% nitrogen.

Irradiating laboratory, IL: A laboratory possessing radiation sources, calibration equipment, and associated facilities that is able to irradiate dosimeters to radiation quantities known to a high degree of certainty.

Particle fluence, ϕ : The quotient of dN by da , where dN is the number of particles incident on a sphere of cross-sectional area da :

$$\phi = \frac{dN}{da} \quad (\text{Eq. 8})$$

Note: The unit of particle fluence is m^{-2} .

Performance criteria: Performance in a given category shall be considered adequate if, for the personal dose equivalent or absorbed dose,

$$B^2 + S^2 \leq L^2 \quad (\text{Eq. 9})$$

where B is the bias and S is the standard deviation for a particular category or subcategory and L is the tolerance level.

The values of the tolerance level, L , shall be $L = 0.24$ in the accident category (category I) and $L = 0.30$ in the other categories.

Performance quotient, P_i : For the i^{th} dosimeter

$$P_i \equiv [H_R(d)_i - H_p(d)_i] / H_p(d)_i \quad (\text{Eq. 10})$$

where $H_p(d)_i$ is the conventional quantity value of the personal dose equivalent assigned by the irradiating laboratory to the irradiated dosimeter and $H_R(d)_i$ is the corresponding personal dose equivalent reported by the test participant.

For the accident category, the same definition applies, with the absorbed dose, D , replacing the personal dose equivalent, $H_p(d)$.

Personal dose equivalent, $H_p(d)$: The dose equivalent in soft tissue as defined in ICRU 51 (ICRU 1993) below a specified point on the body at an appropriate depth d .

Note 1: The individual equivalent dose defined in ICRP 60 (ICRP 1991) is equivalent to the personal dose equivalent defined in ICRU 47 (ICRU 1992).

Note 2: The unit of the personal dose equivalent is joule per kilogram (J kg^{-1}) with the special name sievert (Sv). The special unit of personal equivalent, rem, is 10^{-2} Sv.

Note 3: Any statement of personal dose equivalent should include a specification of the depth, d , expressed in millimeters.

Note 4: Shallow dose equivalent is defined as the personal dose equivalent at a depth of 0.07 mm in ICRU tissue and is denoted by $H_p(0.07)$. In ICRP 60, shallow dose equivalent is given the name *individual dose equivalent, superficial*. Deep dose equivalent is defined as the personal dose equivalent at a depth of 10 mm in ICRU tissue and is denoted by $H_p(10)$. In ICRP 60, deep dose equivalent is given the name *individual dose equivalent, penetrating*.

Processor: A supplier of personnel dosimetry services. These services include (1) furnishing dosimeters to the user, (2) evaluating the readings of the dosimeters after their return in terms of the absorbed dose or personal dose equivalent as prescribed in this standard, (3)

recording the results, and (4) reporting the results to the user.

Radiation field: A region in which ionizing radiation of a known type, energy, and direction is present, and for which intensity can be quantified at one or more points in terms of a field quantity such as fluence or air kerma rate.

Reference dose point, RDP: The point in the radiation field at which the field quantity is specified. For the tests described in this standard, the RDP is on the surface of the phantom along the central ray of the radiation field passing through the center of the phantom.

Reference orientation: The orientation for which the direction of incident radiation coincides with the reference direction (as specified by the test participant) of the dosimeter.

Residual maximum energy, E_{res} : The highest value of the energy of a beta particle spectrum at the reference dose point after having been modified by scatter and absorption.

Standard deviation, S : A statistical measure of the variation in the results, defined as

$$S \equiv \sqrt{\frac{\sum_{i=1}^n (P_i - \bar{P})^2}{n-1}} \quad (\text{Eq. 11})$$

where the sum is extended over all n values of P_i included in the test for a particular test depth and test category or subcategory, and $\bar{P}$, the mean performance quotient, is defined as

$$\bar{P} = (1/n) \sum_{i=1}^n P_i \quad (\text{Eq. 12})$$

Standard test conditions: The range of values of a set of influence quantities under which irradiation of dosimeters is carried out.

Note: Ideally, IL dosimeter irradiations should be carried out under reference conditions. Because this is not always achievable (e.g., for ambient air pressure) or convenient (e.g., for ambient temperature), the calibration factor should, in principle, be adjusted for deviations from reference

conditions. The standard test conditions together with the reference conditions applicable to this standard are given in Appendix G.

Testing organization: A group, independent of the test participant's operation, that administers and evaluates the performance testing of participants. The testing organization may include the IL.

Tolerance level, L : The boundary of acceptable performance of a dosimetry system.

3.0 Test Procedure

This section specifies the performance test procedure. The procedure is summarized below.

- The test participant selects the categories for which evaluation is sought.
- The test participant submits dosimeters, representative of those supplied to customers, to the IL. The participant supplies the number of dosimeters required for testing in the requested test categories.
- The IL irradiates the dosimeters in the radiation field(s) specified for applicable categories.
- The IL returns the dosimeters to the test participant for evaluation.
- The test participant evaluates the response of the irradiated dosimeters in terms of the absorbed dose or personal dose equivalent at the specified test depths.
- The test participant reports the results of the dosimeter evaluation to the IL.
- The testing organization evaluates the dosimeter performance based on criteria in this standard.
- The testing organization notifies the test participant of the dosimeter performance.

3.1 Administrative Procedure

3.1.1 Information to be Supplied to the Irradiating Laboratory The test participant shall provide the following information to the irradiating laboratory:

- The test categories desired.
- A description of dosimeter design including nomenclature, holder, pictures or schematics showing construction.
- Specification of the normal wearing (vertical) orientation and the reference direction of the dosimeter.
- Operating instructions if electronic dosimeters are being tested.

The test participant may supply the distance from the phantom face to the sensitive element(s) with the dosimeter mounted parallel to the phantom face. This parameter is optional and, if provided, may be used by the IL to adjust absorbed doses or personal dose equivalents delivered to dosimeters to account for displacement of the sensitive element(s) from the reference dose point. If it is not supplied, the IL will use the RDP.

3.1.2 Test Schedule A test shall consist of three separate iterations (or rounds) performed over a period of approximately 3 mo. According to the testing organization's or IL's direction, at the start of the testing period the participant will submit to the IL either the total number of dosimeters required for testing or only the dosimeters necessary for the first round of testing. In the latter case, additional dosimeters are submitted for each successive round. The IL will irradiate the dosimeters in each of the three rounds and return irradiated dosimeters to the test participant within 15 calendar days from the end of each round. The test participant should report results within 15 calendar days of receiving the dosimeters. Failure to submit all dosimeter evaluations by the requested date may, at the discretion of the testing organization, result in failure. If for technical reasons the test participant needs to void a reported result, this must be done prior to the IL's reporting the test results.

3.1.3 Number of Test Dosimeters The test participant shall submit 15 dosimeters (5 per round) for each subcategory selected for evaluation, except for the subcategories of category II, which require 21 dosimeters each (7 per round). Additional dosimeters, as specified by the IL, shall be included with each round as control and replacement dosimeters in case problems are encountered.

3.1.4 Information to be Supplied to Test Participants

The IL will report the range of irradiation dates (within a 7- to 10-d window) to the participant to allow correction of dosimeter response for fade. The identities of dosimeters irradiated in category I (accidents) and category V (neutron/photon mixtures), along with control, mis-irradiated, and voided dosimeters, will be reported to the test participant when the testing laboratory returns the dosimeters. In addition, if subcategory IIID is selected with another subcategory in category III, then the identities of dosimeters irradiated with the slab betas will be provided. No information shall be divulged to the test participant for other dosimeters until the test results are released.

The IL will record the readings of all electronic dosimeters prior to shipping them back to the test participant. However, this will only be used in the event that electronic dosimeter measurements are not recoverable by the test participant.

3.1.5 Dissemination of Test Results The irradiating laboratory or testing organization shall report all test results to the participant after the test is completed, including an estimate for the uncertainty of the assigned values of absorbed dose or personal dose equivalent.

3.2 Test Categories

The test categories are given in Table 1a and are described below. Further discussion is included in Appendix A. Dosimeters from participants should be tested in the categories that best represent the services they provide.

3.2.1 Category I – accident, photons High doses from photons from ^{137}Cs and NIST technique M150 are used for the accident category I. In the general subcategory IA, the radiation field in which each dosimeter is to be irradiated shall be chosen at random by the IL with the provision that at least three dosimeters will be irradiated using each source. Subcategories IB and IC use only the specified source for all irradiations.

3.2.2 Category II – photons/photon mixtures This category comprises irradiations to single and mixed photon radiation fields. Its four subcategories provide testing for different

workplace environments. The IL will select 21 dosimeters for testing in category II, regardless of the number or combination of subcategories selected by the test participant. Specific photon radiation fields shall be chosen at random by the IL for each irradiation, subject to the limits on numbers of dosimeters irradiated at non-perpendicular incidence, in mixture combinations, or with low average photon energies as specified in Table 1b. While that table is more comprehensive in its requirements, its major provisions include:

- At least five dosimeters are to be irradiated in a single high-energy photon field ($\bar{E} \geq 500$ keV) at perpendicular incidence only.
- For testing subcategory IIA, no more than five dosimeters will be irradiated with photons with average energies below 100 keV.
- For subcategories IIA, IIC, and IID, at least 5 and no more than 10 shall be irradiated with mixtures. Mixtures always include one irradiation with $\bar{E} \geq 500$ keV and one irradiation with $\bar{E} < 500$ keV.
- For subcategory IID, the specific spectra chosen for testing by the IL are representative of plutonium environments (see Appendix A, Section A2).

Note that each of the four subcategories includes photons with $\bar{E} \geq 500$ keV, so photon/photon mixture irradiations and irradiations at non-perpendicular incidence are included regardless of the subcategory(ies) selected for testing. If any dosimeter is irradiated with an average photon energy less than or equal to 70 keV, or is irradiated as a mixture, the irradiation(s) shall be conducted at perpendicular incidence. If the average energy of the photon field is greater than 70 keV, the angle of incidence for each irradiation shall be chosen at random by the IL from horizontal and vertical dosimeter orientations at angles of 0° , $\pm 40^\circ$ or $\pm 60^\circ$. The maximum number of dosimeters in any given subcategory irradiated at non-perpendicular incidence is specified in Table 1b.

3.2.3 Category III – betas This category comprises irradiations in a single beta particle radiation field. There are four subcategories that provide testing for different workplace environments. All dosimeters are irradiated at

perpendicular incidence. For the general beta subcategory IIIA, the specific beta irradiation field shall be chosen at random from the sources in subcategories IIIB and IIIC by the IL, with the provision that at least three dosimeters shall be irradiated using the high-energy ($\bar{E} \geq 500$ keV) beta source and at least three using the low-energy ($\bar{E} < 500$ keV) beta source. Subcategories IIIB, IIIC, and IIID use only the specified source for all irradiations.

3.2.4 Category IV – photon/beta mixtures

This category comprises irradiations to mixed photon and beta particle radiation fields. Dosimeters tested in this category shall be irradiated at perpendicular incidence in a beta field corresponding to the subcategory in which the participant is tested in category III and in a photon field corresponding to the subcategory in which the participant is tested in category II. If the participant tested in subcategory IIIA, then a beta source shall be chosen at random by the IL for each irradiation with the provision that at least 3 of the 15 dosimeters submitted for testing in this category shall be irradiated using the high-energy beta source ($\bar{E} \geq 500$ keV) and at least three dosimeters using the low-energy beta source ($\bar{E} < 500$ keV). Specific photon radiation fields shall be chosen at random by the IL with the provision that at least three of the dosimeters shall be irradiated in the high-energy ($\bar{E} \geq 500$ keV) photon category. If the specific beta radiation field is low-energy ($\bar{E} < 500$ keV), the high-energy ($\bar{E} \geq 500$ keV) photon field shall be chosen. The ^{60}Co source shall not be used in this category. If two or more subcategories are tested in categories II and III, then multiple tests shall be performed as determined by the testing organization.

3.2.5 Category V – neutron/photon mixtures

This category comprises irradiations to mixed neutron and photon radiation fields. Dosimeters tested in this category shall be irradiated at perpendicular incidence. The specific neutron radiation field used for the general neutron-photon subcategory VA shall be chosen at random by the IL from the D_2O -moderated ^{252}Cf source and the unmoderated ^{252}Cf source with the provision that at least 3 of the 15 dosimeters submitted for testing shall be irradiated using each source. The specific photon radiation field

in category V shall be chosen at random by the IL from the fields in which the dosimeters were tested in category II, with the provision that at least 3 of the 15 dosimeters shall be irradiated

using a high-energy ($\bar{E} \geq 500$ keV) photon source. If two or more subcategories are tested in category II, then multiple tests shall be performed as determined by the testing organization.

Table 1a. Test categories, test irradiation ranges, and tolerance levels

		Test irradiation range	Tolerance level (L)	
			Deep	Shallow
I. Accidents, photons				
A. General (B and C, random)				
B. ^{137}Cs		0.05 to 5 Gy		
C. M150		(5 to 500 rad)	0.24	No test
II. Photons/photon mixtures				
A. General ^a ($\bar{E} \geq 20$ keV; $\perp$ if ≤ 70 keV)				
B. High E (^{137}Cs , ^{60}Co ; $\alpha \leq 60^\circ$)				
C. Medium E ¹ ($\bar{E} > 70$ keV, $\alpha \leq 60^\circ$)		0.5 to 50 mSv		
D. Plutonium specific ^a (see Appendix A, Section A2)		(0.05 to 5 rem)	0.30	0.30
III. Betas				
A. General (B and C, random)				
B. High E ($^{90}\text{Sr}/^{90}\text{Y}$)				
C. Low E (^{85}Kr)		2.5 to 250 mSv		
D. Uranium slab		(0.25 to 25 rem)	No test	0.30
IV. Photon/beta ^b mixtures				
	Shallow	3.0 to 300 mSv (0.30 to 30 rem)	...	0.30
	Deep	0.5 to 50 mSv (0.05 to 5 rem)	0.30	...
V. Neutron/photon mixtures ^c				
A. General (B and C, random)				
B. ^{252}Cf + II		1.5 to 50 mSv		
C. $^{252}\text{Cf}(\text{D}_2\text{O})$ + II		(0.15 to 5 rem)	0.30	No test

^aRatios of $H_p(10)$ for mixtures shall be in the range of 1:3 to 3:1 for subcategories IIA, IIC, IID. Mixtures shall always include one source from subcategory IIB.

^bThe ratio of the [photon $H_p(0.07)$]: [beta particle $H_p(0.07)$] is restricted to be in the range of 1:1 to 1:6, inclusive. There shall be no testing with ^{60}Co .

^cThe ratio of the $H_p(10)$ for neutrons:photons shall be in the range 1:3 to 3:1. The ratio includes the photon component from the neutron irradiation.

Notes:

- Acceptable sources for various categories are defined in the text.
- Non-perpendicular angles are used for single-source irradiations in category II only. The angles are 0° , $\pm 40^\circ$, $\pm 60^\circ$ and include horizontal and vertical dosimeter orientations (see Appendix E, Fig. E1).
- No low-energy ($\bar{E} < 500$ keV) beta particles shall be used with photons with $\bar{E} < 500$ keV in category IV.
- The subcategories chosen in categories II and III shall be used in category IV. The subcategory chosen in category II shall be used in category V.
- For category V, the test applies only to the total value of $H_p(10)$ from neutrons and photons combined (including those from the neutron source).
- No neutron personal dose equivalent < 1 mSv (100 mrem) shall be delivered.
- No more than two dosimeters shall be irradiated to less than twice the minimum dose level.
- No more than two dosimeters shall be irradiated to greater than half of the maximum dose level.
- No component of a photon/photon mixture at either depth shall be less than 0.25 mSv (25 mrem).