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Performance Testing of Extremity Dosimeters

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Foreword

(This foreword is not a part of the American National Standards Institute/Health Physics Society (ANSI/HPS) N13.32-2008.)

This American National Standard provides a procedure for testing the performance of extremity personnel dosimetry systems used to monitor the personnel exposure to the extremities from ionizing radiation. This is the first revision of the original standard, HPS N13.32-1995. Testing the performance of personnel dosimeters has been an active part of evaluation and quality assurance of personnel dosimetry systems.

By ANSI policy, standards must be reviewed and, if necessary, revised every few years. The Health Physics Society working group that reviewed this standard held to three major objectives during revision: (1) as far as possible, maintain an approach to testing consistent with the practical application of extremity dosimeter systems without excluding current and developing techniques; (2) attempt to achieve a measure of consistency with related national and international standards; and (3) base major changes in the approach and content of the standard on scientific fact.

The group identified 12 major issues for consideration. The following paragraphs describe how the group resolved these issues. Some of the issues are treated in greater detail in the appendices, which were written to provide greater insight and convenience. The working group made the most significant changes in the areas of test categories and test criteria.

The working group attempted to harmonize the test categories with those in the whole-body dosimetry testing standard, ANSI/HPS N13.11-2001. Particularly, the photon test categories in the protection level dose range were combined so that the previous test categories for low-energy and high-energy photons, Categories II and III, are now both included in test Category II for photons. In addition, the number of x-ray fields available for testing in the photon category was increased from four x-ray fields and one high-energy photon field to six x-ray fields and two high-energy photon fields. The beta category now included as Category III remains unchanged except for the addition of ^{85}Kr as a replacement for ^{204}Tl .

The working group considered the inclusion of a neutron-testing category based on the recommendation in the *Journal of the ICRU*, Volume 1, No. 3 (2001), "Determination of Operational Dose Equivalent Quantities for Neutrons." At this time, though, the working group felt that the theoretical basis of neutron dosimetry to extremities has not reached a sufficient level of national and international agreement to promote the practice of neutron extremity dosimetry by including a testing category.

At the request of the dosimetry community, one additional test category was added to evaluate response to the beta/photon mixtures (new Category IV). This category was added to accommodate test participants submitting dosimeters with the ability to interpret $H_p(0.07)$ in mixed fields or for dosimeters that are energy/exposure field-independent. If a test participant chooses to test in this category, then that participant will not be told which exposure fields (test sources) were used in any of the categories (Categories I through IV), with the exception that the participant would be told which dosimeters were exposed in the high-dose category (Category I). However, if the participant chooses the "General" subcategory in Category I he or she will not be told whether the irradiating field was ^{137}Cs or M150. This is referred to as *blind testing*. There is no option to only blind-test in Category IV.

Normal testing, as in the previous version of the standard, is not done blindly and includes only Categories I through III. In this case, the testing source is identified to the participant beforehand for the purpose of allowing him or her to apply a specific correction factor to determine a more accurate personal dose (dose equivalent). It is intended that this methodology would be consistent with the methodology for normal processing of personnel dosimeters. That is, the processor would have knowledge of the worker's exposure field and be able to use this information during the determination of the dose equivalent.

The working group modified the ratios of delivered doses for the mixture category to approximate fields more normally found in the industry. The ratios of contributing shallow doses from betas and photons were modified to range from 1:1 to 5:1 (beta:photons).

The working group also considered adding a photon mixture category comprising irradiations in high- and low-energy photon fields. However, based on the response of dosimetry materials to photons with energies above 100 keV, and with the addition of high-energy, broad-spectrum x-ray testing fields, the group considered the testing provided in Category II to be adequate for mixed photon fields.

The selection method for irradiation levels remains unchanged from the previous version of this standard (i.e., the choice of the use of logarithms to increase the number of irradiations at the lower personal dose equivalents).

The working group agreed to the adoption of the personal dose equivalent at 0.07 mm depth or in mass thickness 7 mg cm^{-2} . Research has shown that the dose rate at 0.07 mm used for beta particles incident on the slab phantom is applicable for use with the rod and pillar phantoms (ISO 2006). In selecting personal dose equivalent at 0.07 mm, the working group chose to exclude a discussion of lens dose equivalent (LDE). The group concluded that it was inappropriate to include LDE dose as part of a standard addressing extremity dose.

Conversion coefficients for photons, listed in ISO 4037-3 (ISO 1999), were used with digitized spectra of the National Institutes of Standards and Technology (NIST) x-ray beams to determine coefficients to convert air kerma to personal dose equivalent for the x-ray testing fields. Considering the uncertainties in estimating the extremity exposure in the field, the added uncertainty from this difference in computed conversion factors from air kerma to dose is insignificant.

For practical purposes, the polymethylmethacrylate (PMMA) rod phantom will continue to be used for testing of finger dosimeters.

The working group considered several different designs in selecting a pillar phantom for testing of wrist/ankle dosimeters. They conducted an experiment to determine the differences in the amount of backscatter among designs. Extremity dosimeters were irradiated on a solid PMMA pillar, a water-filled PMMA pillar, an aluminum-core PMMA pillar, and a Styrofoam pillar. Only small differences in dosimeter response were observed among these phantom designs. Therefore, for practical reasons, a solid PMMA phantom, of the same dimensions, was chosen to replace the aluminum-core PMMA phantom described in the previous version of this standard. The study is summarized in Appendix A6.

In the United States, performance test criteria for personal extremity dosimeter systems have historically used a systematic approach (i.e., testing the performance of a group of dosimeters rather than basing the test on individual dosimeter results). This philosophy was continued in the current revision of the standard, and as before there are no individual dosimeter failure criteria to pass. However, the approach to determining group failure criteria has been modified. In the past, group failure criteria were based on (1) not exceeding the tolerance level (L) by the performance index, defined as the sum of the absolute value of the bias ($|B|$) and standard deviation (S) of 15 dosimeters irradiated in a single test category and (2) not exceeding individual limits on the $|B|$ and S in a single test category. In this revision of the standard a new testing model was adopted in which the performance index is redefined as the square root of the sum of the squares of the B and S , consistent with current theory in statistical quality control (see Wheeler and Chambers 1992, in Appendix I of this standard). The resulting performance index is compared to a criteria limit determined by either (1) setting the new performance model's area of acceptable performance equivalent to the previous model's area of acceptable performance or (2) limiting the acceptable values of B and S to historical levels.

There are several notable differences in the two models that could affect the evaluation of performance of dosimetry systems compared to past results. For the high-dose test category, the limit was chosen so the area of acceptable performance was equal to the previous area of acceptable performance (i.e., by equating the area of the triangle formed by $L = |B| + S$ to the area of the half-circle formed by $L^2 = B^2 +$

S^2). This is illustrated in Fig. D1 and results in (1) lowering the maximum allowable individual S and $|B|$ from 0.30 in the old model to 0.24 in the new model and (2) two identical small areas on the graph where the allowable sum of the $|B|$ and S would be greater than 0.30. The probability that a dosimeter system would perform in the affected area of acceptable performance is extremely small. Further, the maximum $|B| + S$ in these small areas for the quadrature model was determined to be 0.34, which is only slightly above the value of 0.30 for $|B| + S$ allowed by the previous model. For the protection level categories, the quadrature model was also adopted and the limit was chosen so the maximum acceptable individual value of the $|B|$ and S would be 0.35, consistent with the previous testing criteria. The maximum $|B| + S$ for the protection level categories was determined to be 0.495, which is only slightly less than the value of 0.50 for $|B| + S$ allowed by the previous model. This is illustrated in Fig. D2.

The performance criterion for the General Beta test (Category IVC in the previous version of the standard and Category IIIA in the current version of the standard) was modified from having no limit on $|B|$ and S in the previous version to a value of 0.35 in the current version as a result of applying the quadrature model to all categories.

The working group modified the required ancillary tests to further distinguish between type tests and periodic performance tests. The requirements for the lower limit of detection (LLD) and angular response testing were removed from this standard because they constitute one-time tests that should be performed upon the initial implementation or modification of a dosimeter system. Recommended protocols for those studies are described in the attached appendices. In addition to those studies, the working group modified the standard to also recommend the study of uncertainty for each dosimeter system. Based on the *U.S. Guide to the Expression of Uncertainty in Measurements*, guidance is given in the appendices for the approach to uncertainty analysis (see ANSI/NCSL 1997, in Appendix 1 of this standard).

Suggestions for improving this standard are welcome. Suggestions should be sent to the Health Physics Society, 1313 Dolley Madison Blvd., Suite 402, McLean, VA 22101.

This standard was consensus-balloted and approved by the ANSI-accredited HPS N13 Committee on November 6, 2007. At the time of balloting, the HPS N13 Committee had the following membership:

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Performance Testing of Extremity Dosimeters

1.0 Purpose

This standard establishes standardized testing conditions and criteria to evaluate the performance of personnel extremity dosimetry services.

1.1 Scope

Specifications are given in this standard for test categories, test irradiation ranges, and acceptable models with associated levels of performance. A test is conducted when dosimeters are sent from the facility that normally processes or reads the dosimeters (i.e., the "processor") to a testing organization that facilitates the irradiation of the dosimeters under controlled conditions specified in this standard. The dosimeters are returned to the processor for evaluation. The results of dosimeter processing are returned to the testing laboratory for evaluation under the criteria given in this standard.

The standard applies to dosimetry systems used to assess personal dose equivalent at a depth of 0.07 mm in ICRU tissue in extremities, specifically, hands or feet and forearms or legs. As such, the standard applies to the performance of dosimeters worn on fingers and on wrists or ankles. Because the basis of the performance test is the personal dose equivalent at a depth of 0.07 mm, this standard does not apply to dosimeters used to assess the dose to the lens of the eye or the personal dose equivalent to the whole body. As in the previous version of this standard, no consideration is given to administrative aspects of dosimetry programs such as adequacy of dosimeter identification, detailed formats of reports, field calibrations, placement of dosimeters on extremities, or the assessment of dose from the placement of multiple extremity dosimeters.

The basis of absorbed dose and dose equivalent in this standard is the personal dose equivalent at 0.07 mm specified in both the International Commission of Radiological Protection (ICRP) and the International Commission on Radiation Units and Measurements (ICRU). Specifically, factors that convert air kerma in photon fields to

personal dose equivalent for rod and pillar phantoms are given in ISO 4037-3 (ISO 1999).

The standard applies to the evaluation of dosimetry performed for radiation protection under low-dose and high-dose conditions in photon and beta fields. The tests for accident dosimetry are approximately represented by the high-dose category.

As in the earlier standard, N13.32-1995 (ANSI/HPS 1995), neutron exposure of the extremities still presents a special problem. The committee reviewed this issue and found no compelling evidence to implement a neutron dose equivalent test for extremity dosimeters at this time. Quoting from the previous standard:

Current neutron fluence-to-dose-equivalent conversion factors specified in recommendations of the NCRP are derived from the maximum value of dose equivalent in a 30-cm diameter cylindrical torso phantom. These values include secondary charged particles from neutron interactions as well as contributions from gamma rays from the absorption of neutrons by hydrogen atoms. The use of data (including the quality factors) from the cylindrical torso phantom model is not applicable for the extremities. Therefore, neutron test categories are not included in this standard. This issue should be re-examined in future revisions of this document or when appropriate fluence-to-dose equivalent conversion factors are established.

A concerted effort has been made in this standard to segregate type-testing issues, typically performed once in the lifetime of a dosimeter system, from periodic performance testing issues. As such, there is no specific requirement to conduct a one-time evaluation of dosimeter performance under conditions of non-perpendicular angular incidence. Neither is there a requirement to conduct a study to evaluate the lower limit of detectability. These tests are important in the interpretation of dosimeter results but should be addressed in a type-testing standard.

The methodology and criteria presented in this standard provide the basis for evaluating the performance of extremity dosimeter systems. Section 2 comprises a list of terms and definitions used in the standard. Section 3

comprises the testing procedures, testing categories, specifications of testing fields, specification of testing phantoms, specification of irradiation geometries, selection of irradiation levels, and the assignment of shallow dose equivalent. Section 4 describes the criteria by which performance is judged to be acceptable.

Following the example set in the standard for testing whole-body personnel dosimeter systems, N13.11-2001 (ANSI/HPS 2001), ancillary information to clarify and support the positions in this standard is included in the appendices.

The scope of this standard is sufficiently comprehensive that satisfactory performance implies that a dosimetry processor or provider is competent to assess personal extremity dose under a broad range of field conditions using the tested dosimetry system.

2.0 Definition of Terms

The definitions for many of the terms used in this standard are given below. The definitions presented for quantities and units are compliant with those of ICRU 51 (ICRU 1993).

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

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

Unit: J kg^{-1}

The special name for the unit of absorbed dose is gray (Gy).

(The special unit of absorbed dose, rad, is 10^{-2} Gy.)

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.

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

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

Unit: J kg^{-1}

The special name for the unit of air kerma is gray (Gy).

(The special unit of air kerma, rad, is 10^{-2} Gy.)

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

$$\bar{E} = \frac{\int_0^{E_{\max}} N(E)E dE}{\int_0^{E_{\max}} N(E)dE} \quad (\text{Eq. 3})$$

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

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 (rod or pillar).

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

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

where, for photons, d is 0.07 mm for the shallow depth and α is the angle of radiation incidence.

Unit: Sv Gy⁻¹ (rem rad⁻¹) for photons

For beta particles, since the field quantity is absorbed dose and the quality factor is unity, the conversion coefficient is unity.

Dose equivalent, H : The product of D and Q at a point in tissue, where D is the absorbed dose and Q is the quality factor at that point, thus

$$H = DQ \quad (\text{Eq. 6})$$

Unit: J kg⁻¹

The special name for the unit of dose equivalent is sievert (Sv).

(The special unit of dose equivalent, rem, is 10⁻² Sv.)

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.

Extremity: The hand and arm below the elbow; the foot and leg below the knee (NRC 2008).

Extremity dosimetry system: A system used to assess dose equivalent resulting from external radiation to the extremities. The extremity dosimetry system includes the dosimeter, the dosimeter processing system and the system used to ensure the quality of the dosimetry result.

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

Homogeneity coefficient: The ratio of the first half-value layer to the second half-value layer, times 100.

ICRU tissue: A tissue-equivalent (TE) material defined in the ICRU Report 33 (ICRU 1980) having a density of 1,000 mg cm⁻³ and a composition by mass of 76.2% O, 10.1% H, 11.1% C, and 2.6% N.

Irradiating laboratory, IL: A laboratory possessing radiation sources, calibration equipment, and associated facilities that is able to irradiate dosimeters from the test sample to

radiation quantities known to a high degree of certainty.

Performance quotient, P_i : The relative difference of the absorbed dose or personal dose equivalent reported by the test participant from the delivered absorbed dose or personal dose equivalent, which for the i^{th} dosimeter is defined as

$$P_i \equiv [H'_i - H_i] / H_i \quad (\text{Eq. 7})$$

where H_i is the personal dose equivalent assigned by the IL to the i^{th} irradiated dosimeter and H'_i is the corresponding personal dose equivalent reported by the test participant.

For tests of high-dose dosimetry, the same definition applies with the absorbed dose, D , replacing the personal dose equivalent, H .

Personal dose equivalent, $H_p(d)$: The dose equivalent dose 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 unit of the personal dose equivalent is joules per kilogram (J kg⁻¹) with the special name sievert (Sv).

Note 2: 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 $H_p(0.07)$.

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 them to the user.

Protection levels: For this standard, protection levels are considered to be below 0.1 Gy (10 rad). The upper end of the regulatory range of protection dosimetry levels is addressed in the "high-dose levels" categories.

Radiation field: A region in which ionizing radiation of a known type, and known spectral and angular distribution, is present and whose intensity is able to 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 coincides with the surface of the phantom along the central ray of the radiation field passing through the center of the phantom, with the exception of irradiations conducted on the slab uranium source. For irradiations conducted on the slab uranium source, the reference dose point is determined empirically as 7 mg cm^{-2} beyond the slab covering that is in contact with 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.

Ring dosimeter: Any dosimeter worn on the fingers of the hand to measure radiation dose, alternatively referred to as a finger or finger-ring dosimeter.

Shallow absorbed dose, $D_p(0.07)$ or shallow dose equivalent, $H_p(0.07)$: The absorbed dose or personal dose equivalent at a depth of 0.07 mm in an appropriate phantom of ICRU tissue. Extremity doses are all expressed as shallow absorbed dose or shallow dose equivalent.

Standard deviation, S : The standard deviation of the values of the performance quotient, P_i , is

$$S \equiv \sqrt{\frac{\sum_{i=1}^n (P_i - \bar{P})^2}{n-1}} \quad (\text{Eq. 8})$$

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 and

$$\bar{P} = (1/n) \sum_{i=1}^n P_i \quad (\text{Eq. 9})$$

Target delivered absorbed dose (D) or target delivered personal dose equivalent (H): This value of D or H that is determined/calculated by the IL and used as a target value to achieve while exposing dosimeters sent for proficiency

testing. Sections 3.9 and A5 use this term in the discussion of the selection of proficiency testing irradiation levels.

Test: Sequence of steps and actions needed to evaluate the performance of personnel dosimeters.

Test category: A collection of radiation qualities and absorbed dose or personal dose equivalent levels for which dosimetry testing is defined.

Test subcategory: A collection of radiation fields in a test category that may include only a limited portion of the energy range of the full category. The general subcategory in each category contains the most comprehensive set of radiation fields (see footnotes on Table 1).

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.

Type test: A test performed on a small number of dosimeters of a given extremity dosimeter system to determine performance characteristics of that dosimetry system and considered to be a one-time determination based on some generally acceptable criteria.

Tolerance level, L : The boundary of acceptable performance of a dosimetry system. For this standard the tolerance level is determined by the following equation:

$$B^2 + S^2 \leq L^2$$

where B is the bias and S is the standard deviation previously defined.

Uncertainty: Parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand (ANSI/NCSL 1997).

Wrist dosimeter. Any dosimeter worn on the wrist or ankle to measure personnel extremity dose.

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 indicates whether the blind testing option is desired.
- The test participant indicates whether wrist or ring dosimeters are being submitted.
- The test participant submits dosimeters, representative of those supplied to users, to the IL over a period of several months. 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 depth.
- The test participant reports the results of the dosimeter evaluation to the IL in the required time.
- The testing organization evaluates the dosimeter performance based on criteria in this standard.
- The testing organization notifies the test participant of the dosimeter's performance.

3.1 Administrative Procedure

3.1.1 Information to be Supplied to the Testing Organization The test participant shall provide the following information to the testing organization:

- A certification that the dosimeters submitted for each test are representative of those supplied to customers.
- The test categories desired.
- An indication of whether blind testing (test category not disclosed to participant before test results are reported) is desired.

- An indication of whether dosimeters are worn on the wrist or as a ring.
- A brief description of dosimeter design, construction, and processing (including a reference to the software version of the dose algorithm).
- A brief description of the dosimeter's orientation on the phantom.
- Known or suspected limiting conditions (e.g., exposure to ambient lighting, dose rate limitations, exposure duration, etc.) that might influence the response of the dosimeter.

3.2 Test Schedule

A test shall consist of three separate iterations (or rounds) performed over a period of 3 to 6 mo. The IL will return test dosimeters to the test participant/user within 45 d of the start of the testing round. The test participant shall report results of evaluations to the IL within 45 d of receiving the dosimeters. Failure by a participant to submit all dosimeter evaluations in a given category within the required 45 d will result in failure of the category.

3.3 Number of Test Dosimeters

The test participant shall submit 15 dosimeters (five per round) for each subcategory selected for evaluation. Two additional dosimeters shall be included in each round as replacement dosimeters in case problems are encountered at the IL. Control dosimeters may be included in each round to evaluate transit doses.

The IL shall not conduct a test for fewer than three processors at a time or the IL shall use an independent and simultaneous method to verify the dose delivered to test dosimeters.

The minimum number of dosimeters that constitute a test for a dosimeter type submitted for testing is 13 in any category. If the dose interpretations from more than 2 of the dosimeters irradiated in a given category are voided because of problems caused by either the IL or the participant, statistical analysis of the results in this category shall be delayed until replacement dosimeters have been submitted and irradiated and the results reported by the processor to the IL.

3.4 Dissemination of Test Results

The testing organization shall report all test results to the participant after the test is completed. An estimate for the uncertainty of the assigned values of shallow dose equivalent shall be available from the IL. The participant shall not be permitted to change or void reported results after the testing organization releases the test results. (Note: circumstances can arise requiring the participant to modify reported doses before the IL distributes the final test reports. After the final test report has been released, each participant is given access to the delivered dose levels for the test and, therefore, cannot modify the test results at that time.)

3.5 Test Categories

Test categories and test dose-equivalent or absorbed dose ranges to be used during the evaluation of extremity dosimetry systems are specified in Table 1. To clarify the notation in the text of Table 1, $\bar{E}$ is meant to be the mean energy of the particular radiation field.

Table 1. Irradiation categories, test irradiation ranges and tolerance levels.

Test category	Test irradiation range	Tolerance level (L) (for $B^2 + S^2 = L^2$)
I. High-dose, photons		
A. General (B and C, random)	0.1 to 5 Gy	0.24
B. ^{137}Cs ($\bar{E} = 662 \text{ keV}$)	(10 to 500 rad)	
C. M150 ($\bar{E} = 73.0 \text{ keV}$)		
II. Photons		
A. General ($\bar{E} \geq 20 \text{ keV}$)	1.0 to 100 mSv	0.35
B. High E ($\bar{E} \geq 500 \text{ keV}$)	(0.1 to 10 rem)	
C. Medium E ($\bar{E} \geq 70 \text{ keV}$)		
D. Narrow spectrum		
III. Betas		
A. General (B and C, random)	2.5 to 100 mSv	0.35
B. High E point source ($\bar{E} \geq 500 \text{ keV}$)	(0.25 to 10 rem)	
C. Low E point source ($\bar{E} < 500 \text{ keV}$)		
D. Slab uranium ($\bar{E} \geq 500 \text{ keV}$)		
IV. Beta/photon mixtures		
A. General photon + beta	3.5 to 100 mSv	0.35
B. Gamma + beta	(0.35 to 10 rem)	

Notes:

1. Only one irradiation below 2.5 mSv is allowed in Category II.
2. Acceptable sources for each category are described in the text.
3. Subcategories chosen in Categories II and III shall be used in Category IV where no subcategories are specified.
4. In Category IV, mixed exposures range from 1:1 to 5:1 (beta:photons), based on the personal dose equivalent.
5. In Category IV, only high-energy ($\bar{E} \geq 500 \text{ keV}$) photons should be used for mixed-source exposures with low-energy ($\bar{E} < 500 \text{ keV}$) betas.

A detailed discussion of each test category listed is included in Appendix A.

It is intended that each participant be tested in the categories that best represent the services they provide. It is also intended that processors employ the same methodology as is normally used for processing personnel extremity dosimeters for a client/user.

Tests in Categories I, II, and III (including all subcategories) are single-field exposures. That is, each individual dosimeter is exposed in only one field.

Tests in Category IV are mixed-field exposures. That is, each individual dosimeter is exposed to two fields, a photon field and a beta field. Mixed-field exposures are not typically performed at the same time because most irradiation laboratories are not equipped for simultaneous exposures from two fields. Typically, mixed-field exposures are performed one at a time with the assumption that the response of the dosimeter would be the same for either method.

Two modes of testing are offered: non-blind and blind. When a participating laboratory only tests in categories I, II, and/or III (i.e., they do not choose Category IV), then dosimeters will be tested with the non-blind option. That is, for each dosimeter tested the participant will be told the irradiation source for the purpose of allowing the participant to apply a specific correction factor to determine a more accurate personal dose equivalent. This is consistent with the way a processor calculates the extremity dose for most single-element extremity dosimeter designs in practice. In these cases, the occupational field is known so a specific correction factor can be used to give a more accurate measurement.

When a participating laboratory chooses Category IV, dosimeters will be blind-tested in all categories tested. The participating laboratory will not be told which sources were used to expose any of the dosimeters, with the exception that the participant would be told which dosimeters were exposed in the high-dose category (Category I). However, under blind testing, if the participant chooses the "General" subcategory in Category I, he or she will not be told whether the irradiating field was ^{137}Cs or M150.

A participating laboratory may choose the blind option to demonstrate greater capabilities of their dosimetry system. Dosimeters capable of blind testing generally have one or both of these design features: (1) they have multiple elements that are used to perform source/energy discrimination, and/or (2) they use nearly tissue-equivalent materials such that source/energy discrimination is unnecessary.

Special subcategories are included for dosimetry in certain types of work environments. Refer to Appendix A for further discussion of work environments and subcategories.

3.5.1 Category I: High-Dose Photons For the "General (B and C, random)" 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 (^{137}Cs and M150).

3.5.2 Category II: Photons For the photon subcategories IIA (General, ($\bar{E} \geq 20$ keV)) and IIC (Medium Energy ($\bar{E} \geq 70$ keV)), specific photon radiation fields shall be chosen at random by the IL for each irradiation with the provision that at least 3 dosimeters of the 15 submitted for testing shall be irradiated in high-energy photon fields ($\bar{E} \geq 500$ keV). For the photon subcategories IIB (High E ($\bar{E} \geq 500$ keV)) and IID (Narrow Spectrum), specific photon radiation fields shall be chosen at random by the IL for each irradiation. Additionally, for all subcategories under Category II, only one dosimeter shall receive an assigned test irradiation less than 2.5 mSv (250 mrem).

3.5.3 Category III: Betas For the "General (B and C, random)" subcategory IIIA, the specific beta irradiation field shall be chosen at random from subcategories IIIB (High E Point Source ($\bar{E} \geq 500$ keV)) and IIIC (Low E Point Source ($\bar{E} < 500$ keV)) 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 shall be irradiated using the low-energy ($\bar{E} < 500$ keV) beta source. The slab uranium (Category IID) source