American National Standard

ANSI/HPS N13.37-2014 (R2019)

Environmental Dosimetry—
Criteria for System Design and Implementation

Approved 8 April 2014
Reaffirmed 23 May 2019

American National Standards Institute, Inc.

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

Published by

Health Physics Society
950 Herndon Parkway
Suite 450
Herndon, VA 20170

Copyright © 2019 by the Health Physics Society.
All rights reserved.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without prior written permission of the publisher.

Printed in the United States of America.

ANSI/HPS N13.37-2014 (R2019)

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

The ANSI/HPS N13.37 working group responsible for the development of this standard had the following members and consultant:

Gladys A. Klemic, Chair	U.S. Department of Homeland Security
Steven Garry	U.S. Nuclear Regulatory Commission
Wayne M. Glines	Dade Moeller & Associates (formerly with the U.S. Department of Energy, Richland Operations Office)
Michael W. Lantz	Mirion Technologies
Bruce A. Rathbone	Pacific Northwest National Laboratory
Phillip Shultz	Dade Moeller & Associates (retired)
Christopher Soares	National Institute of Standards and Technology (retired)
Richard K. Struckmeyer	Consultant, U.S. Nuclear Regulatory Commission

The group gratefully acknowledges valuable contributions from:

Ronald L. Nimitz	U.S. Nuclear Regulatory Commission
Jileen Shobe	Past working group member

The current working group is especially grateful to Dr. E. Gail de Planque and Dr. Marko Moscovitch who served as chairs of previous versions of this standard and who have left a legacy of brilliant research which advanced the field of thermoluminescent dosimetry. Without their efforts and the efforts of other previous working group members, whose work we are continuing, this current standard would not have been possible.

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

This standard was consensus balloted and approved by Accredited Standards Committee (ASC) N13 on 30 December 2013. At the time of balloting, the Committee had the following membership:

Chairperson	Michelle L. Johnson
American Association of Physicians in Medicine (AAPM)	Robert A. Phillips Lynne Fairobent (alternate)
American College of Occupational and Environmental Medicine	Bryce Breitenstein
American Industrial Hygiene Association (AIHA)	Ray Johnson
American Iron and Steel Institute	Anthony La Mastra
American Mining Congress	Scott C. Munson
American Nuclear Insurers	Marcia Anderson Bob Oliveira (alternate)
American Nuclear Society (ANS)	Ali Simpkins
Conference of Radiation Control Program Directors (CRCPD)	Earl Fordham
Council on Ionizing Radiation Measurements and Standards (CIRMS)	Chris Soares
Council on Radionuclides and Radiopharmaceuticals, Inc. (CORAR)	Leonard Smith
Health Physics Society (HPS)	Sandy Perle Wayne Glines (alternate)
Institute of Electrical and Electronic Engineers (IEEE)	Mike Unterweger
Institute of Nuclear Materials Management (INMM)	Skip (Harrison) Kerschner
National Council on Radiation Protection and Measurements (NCRP)	James Cassata
National Registry of Radiation Protection Technologists (NRRPT)	Dwaine Brown
Nuclear Energy Institute (NEI)	Ralph L. Andersen Ellen Anderson (alternate)
US Department of Commerce	Thomas J. McGiff Janna P. Shupe (alternate)
US Department of Energy	Steve Zobel Judy Foulke (alternate)
US Department of Defense	Tim Mikulski John Cuellar (alternate)
US Department of Homeland Security	Peter Chiaro
US Environmental Protection Agency	Mike Boyd
US Nuclear Regulatory Commission	Donald A. Cool
US Navy	Jerry N. Sanders
Individual member	Eric Darois
Individual member	Tracy Ikenberry
Individual member	Greg Komp
Individual member	Joseph P. Ring
Individual member	L. Max Scott
Individual member	Toshihide Ushino

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

Contents

Foreword v

1.0 Purpose and Scope 1
1.1 Purpose 1
1.2 Scope 1
2.0 Definitions 2
3.0 General Considerations 7
3.1 Special Word Usage 7
3.2 Radiation Sources, Quantities, and Units 7
3.2.1 Photons 7
3.2.2 Neutrons 8
3.2.3 Beta Particles 8
3.3 Dosimeter Laboratory Test Protocols 8
4.0 Tabular Summary of Requirements and Recommendations 9
5.0 System Design Criteria: Radiological Type Tests 14
5.1 Uniformity and Reproducibility 14
5.1.1 Uniformity of Dosimeter Response 14
5.1.2 Reproducibility of Dosimeter Response 14
5.2 Photon Energy Dependence 15
5.3 Linearity and Precision 15
5.4 Laboratory-Based Minimum Quantifiable Dose 16
5.5 Dosimeter Orientation in Radiation Field 17
5.6 Neutron Radiation Influence 18
5.7 Beta Radiation Influence 19
6.0 System Design Criteria: Environmental Type Tests 19
6.1 Light Test 20
6.2 Condensing Moisture Test 21
6.3 Low-Temperature Test 21
6.4 High-Temperature Test 21
7.0 Implementation Criteria 21
7.1 Field Monitoring Locations 21
7.2 Control Dosimeters to Account for Extraneous Dose 23
7.2.1 Shielded Storage Vault 23
7.2.2 Accounting for Extraneous Dose 24
7.3 Data Analysis 24
7.3.1 Normalizing to a Standard Monitoring Period 24
7.3.2 Baseline Background Dose for Each Monitoring Location 25
7.3.3 Minimum Differential Dose for the Dosimetry System 25
7.3.4 Facility-Related Dose 25
7.3.5 Dose to a Member of the Public 26
7.4 Quality Assurance Programs 26
7.4.1 Quality Assurance Testing—Blind Spikes 26
7.4.2 Quality Assurance Assessments 27
8.0 Informative References to the Text 27

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

Annexes

Annex A Derivation of Minimum Quantifiable Dose Formula (Informative) 28
Annex B Technical Basis for Testing Neutron Radiation Influence (Informative) 31
Annex C Methods for Determining Baseline Background Dose and Minimum Differential Dose (Normative) 34
Annex D Sample Calculations of MDD_Q, MDD_A, and Facility-Related Dose (Informative) 37

Tables

Table 1 Symbols used in summary Tables 2–4 10
Table 2 System design criteria: radiological type tests 11
Table 3 System design criteria: environmental type tests 12
Table 4 Implementation criteria 13
Table 5 Tabulated format for measurement results in uniformity and reproducibility tests 15
Table 6 Dose levels for linearity test 16
Table 7 Irradiation angles for orientation tests 18
Table A1 Calculated values for n for selected values of CV_8 at large doses 30
Table D1 Example of using historical monitoring data to find MDD_Q and MDD_A 37
Table D2 Example of determination of facility-related dose from quarterly monitoring data 38

Figures

Figure 1 Diagram of dosimeter rotations 17
Figure A1 Relative standard deviation vs. dose curves for TLD systems 30
Figure B1 Coordinate system for anisotropically emitting source 32

Documents
Document Sharing Hub
Full document details: HPS N13.37 2019

Foreword (This foreword is not part of American National Standard ANSI/HPS N13.37-2014)

By American National Standards Institute (ANSI) policy, standards must undergo periodic review and subsequent revision as necessary. The prior ANSI standard to address performance of environmental dosimetry systems was ANSI N545-1975, "Performance, Testing, and Procedural Specifications for Thermoluminescence Dosimetry (Environmental Applications)." In 1991, the Health Physics Society (HPS) Standards Committee appointed a group of experts to (1) revise N545 as N13.37, and (2) develop a new, related standard, N13.29, "Environmental Dosimetry Performance—Criteria for Testing," that would define a test program for environmental dosimetry processors analogous to that for personal dosimetry (see ANSI N13.11, "Personnel Dosimetry Performance—Criteria for Testing"). A draft of ANSI N13.29 was developed by the working group and pilot tested by the Department of Energy (DOE) in 1998. However, since neither the Nuclear Regulatory Commission (NRC) nor DOE established a requirement for environmental dosimeter performance testing, interest and support for N13.29 waned. Concurrently, a voluntary environmental dosimeter intercomparison program established by DOE in 1974 conducted its last intercomparison study in 2000.

In 2009, the HPS received renewed interest in the need for a standard for performance of environmental dosimetry systems from the NRC. In response, the current working group was established in 2011, including some of the members of the earlier N13.29 and N13.37 groups as well as new members from federal agencies and industry. Starting with prior drafts of N13.37, the group reorganized and developed a new standard to reflect current environmental dosimeter applications and input received from environmental dosimetry processors and end users.

In addition to updating and completing the work initiated by prior N13.37 working groups, this standard also serves to complement and extend the technical requirements and guidance in International Standard IEC 62387, "Radiation Protection Instrumentation—Passive Integrating Dosimetry Systems for Personal and Environmental Monitoring of Photon and Beta Radiation." While the performance criteria are generally comparable, by focusing specifically on passive environmental monitoring dosimetry systems, the N13.37 testing approach may be seen as simplified from that in IEC 62387. Additionally, this standard extends beyond IEC 62387 in providing requirements and guidance for deployment and data analysis of environmental monitoring dosimetry systems.

Sections 1 through 4 of this standard cover the overview, definitions, general considerations, and a summary of requirements and recommendations. Sections 5 and 6 cover radiological and environmental type tests that will enable field measurements suitable for quantifying the radiological impact of facility operations on members of the public and the surrounding environment. These tests are intended to be performed once on a specific, documented system design, including the dosimeters, readout equipment, other processing hardware, and dose calculation methods. Section 7 provides implementation performance objectives, requirements, and recommendations for field measurements using a system that has satisfied the performance criteria in Sections 5 and 6.

It should be noted that an environmental dosimetry system that passes all radiological and environmental laboratory type tests described in this standard is not assured of providing accurate field results since subsequent mistakes in data handling can overshadow the performance test tolerances. For example, calculation errors involving transit control dosimeters were regularly observed in the former international intercomparison program; Section 7.2 addresses these types of errors.

Keywords: environmental radiation, environmental monitoring, thermoluminescence dosimetry, TLD, optically stimulated luminescence, OSL, passive dosimeters, facility monitoring, external dosimetry

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

Environmental Dosimetry—Criteria for System Design and Implementation

1.0 Purpose and Scope

1.1 Purpose

This standard provides performance test methods and criteria for system design and implementation of environmental radiation dosimetry systems used to measure external photon radiation.

1.2 Scope

This standard is applicable to passive environmental dosimetry systems used to monitor areas surrounding radiological facilities to assess potential facility-related radiation doses and to verify compliance with public dose limits. Such environmental dosimetry systems include dosimeters which accumulate radiation dose and any readout device required to process the dosimeters. Passive dosimeters include thermoluminescence dosimeters (TLDs), optically stimulated luminescence (OSL) dosimeters, and direct ion-storage dosimeters, which are deployed at field locations around a facility and exchanged periodically (e.g., quarterly). Dosimeters could be processed at the facility or off-site.

Sections 1 through 4 of this standard cover the overview, definitions, general considerations and a summary of requirements and recommendations. Sections 5 and 6 describe laboratory type tests to determine the fundamental performance characteristics of a specified dosimetry system design and establish criteria that will enable a level of bias and precision in field measurements suitable for quantifying the radiological impact of facility operations on members of the public and the surrounding environment. Section 7 of this standard provides implementation performance objectives, requirements, and recommendations for field measurements using a dosimetry system that has satisfied the performance criteria in Section 5 and 6.

Establishing conformance with this standard requires fully documenting the system design. The system design is defined to include the dosimeters, readout equipment and other processing hardware as well as the equipment configuration, operating/processing procedures, and dose calculation methods used for type testing. All of these play a significant role in determining system performance.[1] If a specific documented system design has been tested and shown to meet the performance criteria in Sections 5 and 6, then the test results are applicable to any processor implementing the same system design.

It is important to note that the type tests in Sections 5 and 6 are not intended as tests of a particular processor but rather as tests of a specific system design. Some manufacturers may offer turn-key systems (hardware and software) and recommended operating procedures that have been optimized for environmental monitoring. Others offer systems with flexibility in configuration and operation that allow the processor to design a system tailored to their needs. It is ultimately the processor who determines the final system design that is implemented and which is the subject of the type tests in this standard.[2] It is recognized that the end user must sometimes take certain actions that alter the system design that has been tested (e.g., additional dosimeter packaging or field

[1] For example, with TLD and OSL systems, depending on the particular detector material used, the pre-irradiation anneal treatment and readout protocols (e.g., time-temperature profile for TLD, or optical stimulation wavelength, power, and duration for OSL) can significantly impact the sensitivity, reproducibility, and minimum quantifiable dose for a system, as well as the fading characteristics of the system. The dose calculation algorithms used can significantly influence the angular and energy dependence of dose results. Because routine dose calculation methods are called for in many of the type tests, details of those methods shall be included in the documentation of the system design that is tested.

[2] The distinctions between manufacturer and processor and processor and end user are not always clear. In some cases, the manufacturer and processor may be one and the same, or have a close working relationship. In other cases (e.g., "in-house" dosimetry programs) the processor and end user may be one and the same, or have a close working relationship. The term "processor" is used generically here to refer to the laboratory in which dosimeters are prepared and processed (i.e., readout and results reported to end user).

Documents
Document Sharing Hub
Full document details: HPS N13.37 2019

mounting hardware). When this is the case, the end user shall document that those changes have not altered the basic performance characteristics that were determined in the type tests.

2.0 Definitions

Air kerma (K_a): The quotient of dE_{tr} by dm, where dE_{tr} is the sum of the initial kinetic energies of all the charged particles (e.g., electrons) liberated by uncharged particles (e.g., photons) in mass, dm, of air at a point of interest in air, thus:

$$K_a = dE_{tr}/dm \qquad (1)$$

Note 1: The International System (SI) unit for air kerma is joules per kilogram (J kg^{-1}). The special name for this unit of air kerma is gray (Gy) where 1 Gy = 1 J kg^{-1}.

Note 2: The traditional unit of air kerma is ergs per gram (ergs g^{-1}). The name for this unit of air kerma is rad where 1 rad = 100 ergs g^{-1} (1 rad = 10^{-2} Gy).

Ambient dose equivalent [$H^*(d)$]: The dose equivalent at a point in a radiation field that would be produced by the corresponding expanded and aligned field, in the International Commission on Radiation Units and Measurements (ICRU) sphere at a depth, *d*, on the radius opposing the direction of the aligned field [1].

Note 1: **Dose equivalent** is the product of *D* and *Q* at a point in a given mass, where *D* is the absorbed dose and *Q* is the quality factor at that point, thus

$$H = DQ \qquad (2)$$

Note 2: The SI unit for dose equivalent (and ambient dose equivalent) is joule per kilogram (J kg^{-1}). The special name for this unit of dose equivalent is sievert (Sv) where 1 Sv = 1 J kg^{-1}.

Note 3: The traditional unit of dose equivalent (and ambient dose equivalent) is ergs per gram (ergs g^{-1}). The name for this unit of dose equivalent is rem where 1 rem = 100 ergs g^{-1}. (1 rem = 10^{-2} Sv)

Note 4: The recommended value of *d* for strongly penetrating radiation is 10 mm.

Assessment: A review, evaluation, inspection, test, check, surveillance, or audit to determine and document whether items, processes, systems, or services meet specific requirements and are performing effectively.

Background radiation: Radiation from naturally occurring radioactive materials which have not been technologically enhanced (i.e., not increased by or as a result of past or present human practices above levels encountered in the natural state). Background radiation also includes radiation from the following:

1. Cosmic and terrestrial sources.
2. Global fallout as it exists in the environment (such as from the testing of nuclear explosive devices or from past nuclear accidents which have a global impact [e.g., Chernobyl]).
3. Radon and its progeny in concentrations or levels existing in buildings or the environment which have not been technologically enhanced or elevated as a result of current or prior human activities.
4. Consumer products containing nominal amounts of radioactive material or producing nominal amounts of radiation.

Baseline background dose (B_Q or B_A): The estimated mean background radiation dose at each field monitoring location in a specified time period (e.g., quarterly [B_Q] or annually [B_A]) based on historical measurements, excluding any dose contribution from the monitored facility.

Bias: The mean deviation from the conventionally true value, expressed as a fraction of the conventionally true value, that remains constant over replicated measurements within the statistical precision of the measurement.

Note: Also referred to as deterministic error, fixed error, and systematic error.

Coefficient of determination ($\mathcal{R}^2$): The measure of the proportion of the variance accounted for by an independent variable in predicting the dependent variable. The greater the coefficient, the more account is

Documents
Document Sharing Hub
Full document details: HPS N13.37 2019

taken for the variance. It can range from 0 to 1, and is calculated as follows:

$$\mathcal{R}^2 = 1 - \frac{\text{explained variation}}{\text{total variation}} = 1 - \frac{\sum(\bar{Y} - Y_{\text{est}})^2}{\sum(Y - \bar{Y})^2} \quad (3)$$

where Y are the observed values for the dependent variable, $\bar{Y}$ is the mean of these observed values, and Y_{est} are the predicted or estimated values of the dependent variable. When used in linear regression, the better the linear regression fits the data, the closer the value of $\mathcal{R}^2$ is to one.

Coefficient of variation (CV): The quotient of the estimated standard deviation of a series of measurements, $x_1, x_2, \ldots x_i, \ldots x_N$, of a variable divided by the mean value, $\bar{x}$, of the measurements; or, for a single measurement, the quotient of the estimate of the standard deviation divided by the value of the single measurement.

$$\text{CV} = \frac{1}{\bar{x}} \cdot \sqrt{\frac{1}{(N-1)} \sum_{i=1}^{N} (x_i - \bar{x})^2} \quad (4)$$

where

$$\bar{x} = \frac{1}{N} \cdot \sum_{i=1}^{N} x_i \quad (5)$$

Note: Sometimes expressed as a percentage; i.e., value of coefficient of variation multiplied by 100.

Control dosimeter: A dosimeter that accompanies a field dosimeter to account for extraneous dose received before or after field deployment, such as during transit from and to a dosimeter processor, and/or to and from the field location.

Conventionally true value ($\mathcal{D}$): The best estimate of the delivered radiation dose, determined by (1) a primary standard, (2) a transfer standard that is traceable to a primary standard, or (3) a reference instrument that has been calibrated against a primary or a transfer standard.

Coverage factor: A numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty.

Note 1: A coverage factor is typically in the range 2 to 3.

Note 2: In case of a normal distribution, using a coverage factor of 2 results in an expanded uncertainty that defines an interval around the result of a measurement that contains approximately 95% of the distribution of values that could reasonably be attributed to the measurand. For other distributions, the coverage factor may be larger.

Detector: The radiation sensitive component or material which can be processed to provide a numerical measure of the incident radiation dose, such as an individual TLD element. See definition for dosimeter.

Directional dose equivalent [$H'(d, \Omega)$]: The dose equivalent at a point in a radiation field that would be produced by the corresponding expanded field, in the ICRU sphere at a depth, d, on a radius in a specified direction, Ω.

Note 1: The units and names of units for directional dose equivalent are the same as for ambient dose equivalent.

Note 2: The recommended value of d for weakly penetrating radiation is 0.07 mm.

Note 3: When not specified, Ω is assumed to be zero degrees or of normal incidence.

Dose (radiation dose): A generic term that means absorbed dose, dose equivalent, ambient dose equivalent, or directional dose equivalent, dependent upon context, as defined elsewhere in this standard.

Dosimeter: Device consisting of one or more detectors, which can be mounted in one or more holders functioning as a single unit (appropriate for the application), intended to be placed in a location in the environment for the purpose of measuring ambient dose equivalent at the location where it is placed.

Dosimetry system: The dosimeters, related data collection and processing instruments, and techniques required to evaluate the dose received by environmental dosimeters.

End user: The entity that uses the dosimeters for environmental monitoring purposes, including field deployment and

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

collection of dosimeters. Where processing is done off-site, the end user also handles receipt of dosimeters from and submission back to the processor.

Environmental monitoring: The measurement of external photon dose using field dosimeters positioned at fixed outdoor locations.

Exposure (*X*): Exposure, *X*, is the quotient of d*Q* by d*m* where d*Q* is the absolute value of the total charge of the ions of one sign produced in air when all of the electrons and positrons liberated or created by photons in air of mass d*m* are completely stopped in air. The SI unit of exposure is C kg^{-1} and the traditional unit is the roentgen (R) with the conversion of 1 R = 2.58 × 10^{-4} C kg^{-1}. Air kerma, K_a, has replaced exposure as the reference quantity used to establish traceability to the U.S. National Institute of Standards and Technology (NIST).

Extraneous dose: The dose accumulated on a dosimeter prior to and after field deployment from radiation other than that at the field monitoring location. The extraneous dose includes any dose received during transit to or at the monitored facility; e.g., natural terrestrial background radiation, cosmic sources, elevated dose from transport at high altitudes, any manmade sources potentially encountered in transit or at the facility, such as shipments of medical or other radioisotopes or facility sources. The extraneous dose is subtracted from the field dosimeter reading in order to determine the field dose.

Facility-related dose (F_Q or F_A): The dose received by a field dosimeter at a monitoring location due to radiation from the monitored facility. Facility-related dose excludes the background radiation dose, which is estimated by use of the baseline background dose. The facility-related dose can be calculated for those monitoring locations where the normalized quarterly field doses M_Q (or normalized annual dose M_A) exceed the baseline background dose by more than the quarterly minimum differential dose (MDD_Q) (or annual MDD_A) as follows.

Quarterly facility-related dose (F_Q):

If $M_Q > (B_Q+MDD_Q)$ then $F_Q = M_Q – B_Q$
If $M_Q \leq (B_Q+MDD_Q)$ then F_Q = not detected

Annual facility-related dose (F_A):

If $M_A > (B_A + MDD_A)$ then $F_A = M_A – B_A$
If $M_A \leq (B_A + MDD_A)$ then F_A = not detected

Field dosimeter: A dosimeter designated for deployment at a field monitoring location.

Field dosimeter gross measurement (M_{FG}): The measurement of dose received by a field dosimeter between annealing and processing, which includes extraneous dose, field background radiation dose, and any facility-related dose.

ICRU sphere: A sphere of 30-cm diameter made of tissue equivalent material with a density of 1 g cm^{-3} and a mass composition of 76.2% oxygen, 11.1% carbon, 10.1% hydrogen, and 2.6% nitrogen; used as a reference phantom in defining dose equivalent quantities.

Mean: As used in this standard, mean refers to the arithmetic mean which is the quotient of the sum of the individual magnitudes of a set of data or measurements and the total number of data or measurements in the set:

$$\bar{x} = \frac{1}{N} \cdot \sum_{i=1}^{N} x_i \qquad (6)$$

Measured field dose (M_F): The dose received by a field dosimeter while deployed at a monitoring location during a monitoring period, which includes both field background radiation dose and any facility-related dose. It does not include the extraneous dose. The field dose at each monitoring location is calculated by subtracting the extraneous dose from the field dosimeter gross measurement, M_{FG}.

Minimum differential dose (MDD_x): The smallest amount of facility-related dose at each monitored location in a specified time period (*x*), above the baseline background dose that can be reliably detected by an environmental dosimetry system. MDD_Q (MDD_A) is the quarterly (annual) minimum differential dose. Due to natural background variations and measurement sensitivities

Documents
Document Sharing Hub
Full document details: HPS N13.37 2019

and uncertainties, the minimum differential dose is greater than zero. As it is based on field results, the minimum differential dose is distinct from the minimum quantifiable dose which is based on laboratory irradiations.

Minimum quantifiable dose (MQD): The smallest delivered dose above which the measurement process can provide results with a standard deviation that is less than or equal to 7% of the delivered dose. In this standard, the minimum quantifiable dose is determined for measurements of dose delivered in laboratory irradiations and is distinct from the minimum differential dose for facility-related radiation.

Monitoring period: The time period between field dosimeters' deployment to and retrieval from the field. This standard generally assumes that the monitoring period is a calendar quarter, but in doing so does not preclude other, end-user-specific monitoring times such as monthly, six-month, or annual periods. (*Note*: The duration of the monitoring period is used in normalizing the quarterly field dose to a 91-day time period).

Monitoring period storage dose: For environmental dosimetry programs that store control dosimeters in a shielded vault during the monitoring period, this is the dose received by a control dosimeter while stored separately from the field dosimeters. The monitoring period storage dose is determined using the elapsed separation time and the known dose rate in the vault for subtraction from the control dosimeter readings in order to determine the extraneous dose. Monitoring period storage dose does not include dose received before or after the monitoring period, even if the field and control dosimeters are temporarily stored in a shielded storage vault while waiting deployment or after field dosimeters are returned from the field while awaiting return to the processor. The dose received during temporary storage periods before or after the monitoring period is included in the extraneous dose and is not considered monitoring period storage dose.

Normalized quarterly field dose (M_Q): Measured field dose (M_F) adjusted to a standardized 91-day period of time. This correction adjusts for the actual number of days of field deployment, which could vary depending on such factors as weather, staff availability, holidays, and the fact that the number of days in a year is not exactly divisible by four. The normalized quarterly field dose is given by

$$\mathrm{M_Q} = \mathrm{M_F} \times \frac{\text{91 days}}{\text{no. of days in field}} \qquad (7)$$

The corresponding normalized annual dose M_A is then the sum of the four normalized quarterly doses. (See definition for monitoring period.)

Performance measure: An equation used to quantify the result of a performance test. Two performance measures are used in this standard—the response and the relative response.

Performance quotient (P): A measure of the agreement of an individual dosimeter result with the corresponding conventionally true value.

Performance requirement: An acceptable value (or range of values) for a given performance measure in order to demonstrate compliance with this standard.

Performance test: A test of an environmental dosimetry system(s) and components to verify that acceptable designed-in performance characteristics are being achieved or to detect any abnormal performance characteristics for which corrective actions should be evaluated.

Precision: The degree of agreement of repeated measurements of the same system or component characteristic expressed in terms of the dispersion of measurement results about the mean result. A measurement of precision can be obtained by repetitive testing of a system or component under specified conditions. The precision is expressed quantitatively as either the standard deviation computed from the measurement results or as the coefficient of variation of the measurement results.

Processor: The entity that provides dosimeters to the end user, receives them back from the end user after the monitoring

Documents
Document Sharing Hub

Full document details: HPS N13.37 2019

period, processes the dosimeters, and reports the measured doses to the end user.

Quality assurance: A management system of planned and systematic actions necessary to provide a given level of confidence that a system or component will perform satisfactorily in service and provide acceptable results or service.

Radiation (ionizing radiation): In the context of this standard, radiation refers to ionizing radiation which is any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, by interaction with matter.

Radiation field: A region in which ionizing radiation of a known type and 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 air kerma or fluence.

Note: **Fluence** (Φ) is the quotient of d*N* by d*a*, where d*N* is the incremental number of particles incident on a sphere of cross-sectional area d*a*. The SI unit of fluence is m^{-2}; a widely used unit is cm^{-2}. The full specification of fluence includes the specification of the kind of particles (e.g., neutrons). The **fluence rate** (φ) is the quotient of dΦ by d*t*, where dΦ is the increment of fluence in time interval d*t*. The SI unit of fluence rate is $m^{-2}\ s^{-1}$; a widely used unit is $cm^{-2}\ s^{-1}$.

Reference dose point: The point in the radiation field at which a performance test field quantity is specified.

Reference radiation field: A radiation field used to expose environmental dosimeters for testing purposes produced by a source of radiation for which the conventionally true value has been determined and is certified traceable to a national standard with an expanded relative uncertainty in the field quantity delivered to the dosimeter of less than 5% at the 95% confidence level.

Relative response (r): The ratio of the response of an environmental dosimetry system or component when specified environmental or exposure conditions are varied, R_R, to its response under reference conditions R_{ref}:

$$r = \frac{R_R}{R_{ref}} \tag{8}$$

For example, the ratio of the response of the dosimeter in conditions of condensing moisture to the response under reference conditions could be used to quantify the environmental sensitivity of the dosimeter to moisture.

Response (R): The quotient of a measured value, M, and its conventionally true value, $\mathfrak{D}$.

$$R = \frac{M}{\mathfrak{D}} \tag{9}$$

Standard deviation S_x: A statistical measure of the variation in the results of a given performance test, calculated as

$$S_x = \sqrt{\frac{1}{(N-1)}\sum_{i=1}^{N}(x_i - \bar{x})^2} \tag{10}$$

where

$$\bar{x} = \frac{1}{N} \cdot \sum_{i=1}^{N} x_i \tag{11}$$

N = the number of test results
x_i = the values of the test results

Note: If the performance measure is a response (R or r), the standard deviation is dimensionless. If the performance measure is a measured value, the standard deviation has the same dimensions as the test result (e.g., ambient dose equivalent).

Type test: A test performed on an environmental dosimetry system to establish conformance to specified radiological and environmental performance criteria. A type test is generally considered to be a one-time determination for the particular system design tested.

Uncertainty: A parameter associated with the result of a measurement, or set of measurements, that characterizes the dispersion of the values that could reasonably be attributed to the measurand (e.g., standard deviation).

Note 1: The **measurand** is the particular quantity subject to measurement.

Note 2: The **combined uncertainty** is the standard deviation of the result of a

Documents
Document Sharing Hub
Full document details: HPS N13.37 2019

measurement, or set of measurements, when the result is dependent upon the values of a number of other quantities. The combined uncertainty is obtained by combining the individual standard uncertainties (and covariances as appropriate) of these quantities, using the law of propagation of uncertainties, commonly called the root-sum-of-squares or RSS method.

Note 3: The **expanded uncertainty** is the product of the combined uncertainty of the result of a measurement, or a set of measurements, and a coverage factor (typically a value between 2 and 3) chosen so that the desired interval has a high probability of containing the value of the measurand. [2]

Note 4: The **relative uncertainty** is the quotient of the uncertainty of the result of a measurement, or a set of measurements, and the absolute value of the result of the measurement, or set of measurements. (The value of the result of the measurement or set of measurements cannot equal zero.) This is sometimes expressed as a percentage (i.e., value of relative uncertainty multiplied by 100).

Note 5: The **relative expanded uncertainty** is the quotient of the expanded uncertainty of the result of a measurement, or a set of measurements, and the absolute value of the result of the measurement, or set of measurements. (The value of the result of the measurement or set of measurements cannot equal zero.) This is sometimes expressed as a percentage (i.e., value of relative uncertainty multiplied by 100).

Note 6: The **standard uncertainty** is the estimated standard deviation of the result of a measurement, or a set of measurements.

3.0 General Considerations

3.1 Special Word Usage

The word “shall” is used to denote a requirement. The word “should” is used to denote a recommendation. To conform to this standard, an environmental dosimetry system shall be performance tested and operated in accordance with its requirements but not necessarily in accordance with its recommendations. However, justification shall be documented for any deviations from recommendations.

The term “normative” refers to direction or information which shall be considered part of this standard and is required for conformance to this standard. The term “informative” refers to information which is not part of this standard and for which conformance is not required.

3.2 Radiation Sources, Quantities, and Units

Reference radiation sources required for type tests are described below. Photon sources are used to test dosimeter performance, while beta and neutron sources are used to determine potential beta and neutron influences. The delivered air kerma for photons from ^{137}Cs and ^{60}Co, directional dose equivalent to tissue at 7 mg cm^{-2} for betas, and fluence rate for neutrons at the reference dose point shall be traceable to NIST. Air kerma for photons from ^{241}Am shall be traceable to the United Kingdom National Physical Laboratory or other national primary standards laboratories. All dosimeters shall be exposed free-in-air.

3.2.1 Photons. For photon irradiations, the primary reference radiation field and exposure geometry shall meet the following criteria:

- Reference source: ^{137}Cs (662 keV).
- Exposure distance: 1–2 m.
- Exposure geometry: free-in-air (i.e., dosimeter suspended in air or mounted on film or low-density foam board).
- Scatter contribution: scattered radiation should contribute less than 5% of the total ambient dose equivalent at the reference dose point. To help achieve this, the reference dose point should be greater than 2 m from nearest wall, floor, or ceiling for both collimated and noncollimated fields. Generally, the distance between the dosimeter and the nearest solid scatter surfaces should be twice the distance between source and dosimeter.
- Reference quantity: ambient dose equivalent at 10 mm depth, $H^*(10)$.

Documents
Document Sharing Hub
Full document details: HPS N13.37 2019