U.S. NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REGULATORY RESEARCH

June 2014
Revision 2

DRAFT REGULATORY GUIDE

Contact: Steven Garry
(301) 415-2766

DRAFT REGULATORY GUIDE DG-4019

(Proposed Revision of Regulatory Guide 4.13, Rev. 1, dated July 1977)

ENVIRONMENTAL DOSIMETRY - PERFORMANCE SPECIFICATIONS, TESTING, AND DATA ANALYSIS

A. INTRODUCTION

Purpose

Environmental dosimetry methods such as Thermoluminescence dosimetry (TLD) and Optically Stimulated Luminance dosimetry (OSL) are widely used to measure levels of X and gamma radiation for environmental purposes at NRC-licensed nuclear facilities. This guide provides acceptable dosimeter design specifications, methods of testing, dosimeter deployment, and data analysis. The data analysis methods provide an acceptable method of determining the facility-related, direct radiation dose in the general environment outside the nuclear facility suitable for demonstrating compliance with the Environmental Protection Agency (EPA) 40 CFR 190, "Environmental Radiation Protection Standards for Nuclear Power Operations" (Ref. 1).

Applicable Rules and Regulations

- Title 10 of the *Code of Federal Regulations* (10 CFR), Part 20, (Ref. 2) Section 20.1301, "Dose limits for individual members of the public" provides limits on the total effective dose equivalent to individual members of the public from the licensed operation.

- 10 CFR 20.1302, "Compliance with dose limits for individual members of the public" requires demonstration by measurement or calculation that the dose to members of the public does not exceed the annual dose limits (including the dose limits of EPA's generally applicable environmental radiation standards in 40 CFR 190). 10 CFR Part 20 Subpart F, "Surveys and Monitoring" further requires that a licensee conduct surveys as may be necessary to comply with the regulations of 10 CFR Part 20 including, when appropriate, the measurement of levels of radiation.

- 10 CFR 20.1501(a), requires each licensee to make or cause to be made, surveys of areas, including the subsurface, that may be necessary to comply with the regulations, and are reasonable under the circumstances to evaluate the magnitude and extent of radiation levels, the concentrations or quantities of residual radioactivity, and the potential radiological hazards of the radiation levels and residual radioactivity detected.

- 10 CFR 20.1501(c) requires that instruments and equipment used for quantitative radiation measurements (e.g., dose rate and effluent monitoring) are calibrated periodically for the radiation measured.

- 10 CFR Part 50, (Ref. 3), Section 50.36 (a), "Technical Specifications on Effluents from Nuclear Power Reactors," which requires that licensees estimate the maximum potential annual radiation doses to the public resulting from effluent releases.

- 10 CFR 50, Appendix I, Paragraph IV.B(2), "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," requires that licensees establish appropriate surveillance and monitoring programs to provide data on measurable levels of radiation and radioactive materials in the environment.

- 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants," Criterion 64, "Monitoring Radioactivity Releases," requires that nuclear power plant designs provide means for monitoring the plant environs for radioactivity that may be released as the result of normal operations, including anticipated operational occurrences, and as the result of postulated accidents.

Related Rules and Regulations

- 10 CFR 20.2202, "Notification of Incidents," requires each licensee to immediately report any event involving byproduct, source, or special nuclear material possessed by the licensee that may have caused or threatens to cause an individual to receive a dose meeting the limits of this Section of the NRC regulations.

- 10 CFR 20.2203, "Reports of Exposure, Radiation Levels, and Concentrations of Radioactive Material Exceeding the Constraints or Limits," requires a report to be sent to the NRC describing the reportable event.

- 10 CFR 20.2205, "Reports to Individuals of Exceeding Dose Limits," requires when a licensee is sending a report to the NRC of any exposure of an identified occupationally exposed individual, or an identified number of the public, to radiation or radioactive material, the licensee shall also provide the individual a report of the data included in the report to the NRC.

Related Guidance

- ANSI N545-1975 "Performance, Testing, and Procedural Specifications for Thermoluminescence Dosimetry (Environmental Applications)," Provides minimum acceptable performance of TLDs used for environmental measurements. (Ref. 4)

- ANSI/HPS N13.37–2014, "Environmental Dosimetry," provides improved methods of performance testing and establishes performance criteria and improved methods of analyzing environmental data to determine potential radiological impacts of facility operations (Ref. 5).

- Regulatory Guide 4.1, "Radiological Environmental Monitoring for Nuclear Power Plants" (Ref. 6)

- Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste" (Ref. 7).

Purpose of Regulatory Guides

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

Paper Reduction Act

This regulatory guide contains information collection requirements covered by 10 CFR Part 20 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0014. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

Reason for Revision

The 1977 (Revision 1) version of this Regulatory Guide (RG) endorsed (with exceptions) the American National Standards (ANSI) N545 (1975) "Performance, Testing, and Procedural Specifications for Thermoluminescence Dosimetry (Environmental Applications)." ANSI N545 has since been withdrawn (removed from circulation) and superseded by the American National Standards Institute/Health Physics Society (ANSI/HPS) N13.37 – 2014, "Environmental Dosimetry."

Since the bases document for RG 4.13, Rev.1 has been replaced, the US NRC is revising RG 4.13. The RG 4.13, Rev. 2 (2014) is being issued to provide improved data analysis methods acceptable for demonstrating compliance with regulatory requirements 10 CFR 20.1301(e); i.e., the Environmental Protection Agency (EPA) 40 CFR 190, "Environmental Radiation Protection Standards For Nuclear Power Operations." This EPA standard establishes a dose limit of 25 mrem whole body, 75 mrem to the thyroid, and 25 mrem to other organs for a real member of the public in the general environment (i.e., in the unrestricted area).

Background

In 1975, the ANSI Committee N13 on Radiation Protection prepared the ANSI N545 standard that specified minimum acceptable performance of TLDs used for environmental measurements; outlined methods to test for compliance; and provided procedures for calibration, field application, and reporting. ANSI N545 was subsequently approved and designated N545-1975 on August 20, 1975.

In ANSI N545, Appendix C, "Interpretation of Field Exposures to Isolate Contributions Attributable to Man-Made Radiation Sources (Such as a Nuclear Power Plant)" guidance was provided on acceptable methods of interpreting environmental monitoring results. In summary, the ANSI N545 guidance provided two methods of data analysis based on the premise that background dose rates were either 1) invariant with location or 2) invariant with time, as follows:

1. Invariant with location: If background dose rates are assumed invariant from one monitoring location to another, then dosimetry measurements could be made at control stations (i.e., a field site remote from a nuclear facility) and compared to the measured background (or changes in background) at indicator stations (i.e., field sites near the facility).

2. Invariant with time: If background dose rate were invariant with time, then dosimetry measurements could be made at each monitoring location and compared to prior measurements at the same location.

Note: The ANSI N545 recognized that neither assumption was strictly valid; however, ANSI N13.37 provides improved data analysis methods for background dose rates invariant with time. This method compares current dosimetry measurements at each monitoring station with previous measurements at the same location.

The ANSI/HPS N13.37 (2014) complements and extends 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" (Ref. 8). 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 by providing requirements and guidance for deployment and data analysis of environmental monitoring dosimetry systems.

Harmonization with International Standards

The NRC has a goal of harmonizing its guidance with international standards, to the extent practical. The International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) have issued a significant number of technical guidance documents, and recommendations addressing good practices in most aspects of radiation protection. Such documents include:

- The International Standard IEC 62387, "Radiation protection instrumentation – Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation," IEC/CEI 62387-1:2007, March, 2012.

The NRC encourages licensees to consult this international document and implement the good practices that are consistent with NRC regulations. It should be noted, however, that some of the recommendations issued by these international organizations do not correspond to the requirements specified in the NRC's regulations. In such cases, the NRC's requirements take precedence.

Documents Discussed in Staff Regulatory Guidance

Although this regulatory guide utilizes information, in part, from one or more reports developed by external organizations and other third party guidance documents, the regulatory guide does not endorse

these references other than as specified in this regulatory guide. These reports and third party guidance documents may contain references to other reports or third party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that requirement in the regulation. If the secondary reference has been endorsed in a regulatory guide as an acceptable approach for meeting an NRC requirement, then the reference constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific regulatory guide. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a regulatory guide, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC approval as an acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified and consistent with current regulatory practice, consistent with applicable NRC requirements such as 10 CFR Part 20.

C. STAFF REGULATORY GUIDANCE

1. Quantitative Measurements

Environmental dosimetry programs should provide accurate quantitative radiation measurements and analyses that are capable of demonstrating compliance with regulations 10 CFR 20.1301 and EPA 40 CFR 190. In order to do this, dosimetry systems should:

- Meet environmental type testing criteria for system design
- Meet radiological type testing for accuracy, precision, and linearity criteria
- Be capable of measuring a quarterly dose of 20 mrem with a coefficient of variation not to exceed ~7%
- Be capable of determining a facility-related dose of ~ 5 mrem per quarter or ~ 10 mrem per year

2. Regulatory Guide 4.13, Rev. 1 (1977)

RG 4.13, Rev. 1 (1977) continues to provide methods acceptable to NRC to demonstrate compliance with the public dose limits of 10 CFR 20.1301. This 1977 version established the NRC position that the ANSI N545-1975 standard is generally acceptable as a basis for using environmental dosimetry for measurement of direct radiation in the environs, subject to the stated additional provisions and qualifications listed in the Regulatory Guide 4.13, Revision 1.

Environmental dosimetry systems in current use that have been demonstrated to meet the Regulatory Guide 4.13, Revision 1 criteria do not need to be retested to the radiation and environmental type tests of ANSI/HPS N13.37-2014. However, licensees should have documentation that the environmental dosimetry system has been tested and meets the criteria of RG 4.13, Revision 1 (or equivalent), and provide adequate methods of data analysis to identify facility-related dose.

3. ANSI/HPS N13.37 (2014)

ANSI/HPS 13.37 (2014) provides improved acceptance criteria and data analysis methods for analysis of direct radiation in the environs of NRC-licensed facilities. This Regulatory Guide endorses the

ANSI/HPS N13.37 standard as providing acceptable methods of performance testing environmental dosimetry and analyzing environmental monitoring data.

4. Data Analysis Techniques provided in ANSI N13.37

An analysis of environmental dosimetry measurements must be analyzed using acceptable scientific techniques. Data should be analyzed for each monitoring period (in lieu of annual review) so that corrective actions can be taken promptly.

The first step in this method is to identify obvious data outliers and investigate apparent discrepancies. This data should be analyzed before data corrections/adjustments (e.g., subtraction of extraneous dose) (see definitions in Appendix A) or data normalizations occur (e.g., adjusting data to a normalized, 91 day monitoring period).

Acceptable analysis methods include analyzing results for each monitored location independently from the other locations:

a. Evaluate Element Readings
   i. Obtain element readings (from the field dosimeters, dosimeters at a control station, and control dosimeters stored in lead shield). Note the distinction in terminology between "dosimeters at a control station" (remote from the facility) and "control dosimeters stored in a lead shield."
   ii. Identify characteristics of each element's filtration and /or phosphor (so that element reading outliers can be properly determined).
   iii. Perform a qualitative review of the element readings, and identify and investigate any obvious outliers and make notations as to the circumstances
   iv. Calculate[1] the standard deviation (SD) and the coefficient of variation (CV) of the remaining (credible and valid) element readings (i.e., after outliers have been removed from the data set)
   v. Review SD and CV data (i.e., for those elements expected to measure the same dose quantity based on the same filtration or same phosphor). Identify and document the reason for CVs greater than 10%.
   vi. Calculate the valid (after removal of outliers) "gross" field dosimeter readings (i.e., the field dose plus the extraneous dose) for each monitored location. Note: Data from dosimeters located at control stations is not particularly relevant in an analysis method that is "invariant with time," but the dosimeter readings at control stations should be evaluated anyway and reported for consistency.
   vii. Calculate the valid control dosimeter doses (i.e., after removal of outliers based on control dosimeters stored in a lead shield)

b. Determine The Extraneous[2] Dose

1 The SD and the CV of a small data set are not accurate measures of performance, but do provide an initial indication of performance.

[2] Extraneous dose (e.g., storage dose, transit dose) has been the least understood process over the history of these measurements. ANSI/HPS N13.37 provides details on proper methods of determining extraneous dose. Onsite processors can minimize extraneous dose by performing the processing very soon before deployment and after collection.

i. Determine the mean (average) dose on control dosimeters stored in a lead shield.
ii. Calculate the extraneous dose (the dose that the field dosimeters accrued while not deployed in the field). Note: The mean control dosimeter dose is not an adequate measure of the extraneous dose. See ANSI N13.37 methods of determining extraneous dose.

c. Determine Field Doses

i. Determine the accrued field dose at each monitored location by subtracting the extraneous dose. Note: A simple subtraction of the control dosimeter readings from the field dosimeter readings is not an accurate method of assessing field dose.
ii. Normalize the data to a standard 91-day quarter (or other normalized period).
iii. Perform a qualitative comparison of the normalized, quarterly field doses to the base-line background dose rate for each monitored location.
iv. Identify apparent outliers and investigate anomalies.
v. Remove substantiated outliers from the data set and document justifications.

d. Determine the dosimetry system's quarterly and annual minimum detectable dose (MDD). Note: The MDD accounts for 3 standard deviations in measurements.

e. Determine the base-line background dose rate (at each monitored location).

f. Determine Quarterly Facility-Related Doses (at each monitored location)

i. Sum the quarterly MDD and the quarterly baseline background dose rate.
ii. Subtract the sum from the normalized field dose (to determine the facility-related dose).
iii. Identify any detectable facility-related dose (e.g., exceeding 5 mrem during the quarterly period).
iv. Investigate any detectable facility-related dose, and document substantiated facility-related dose, and remove (with justification) any unsubstantiated doses from the data set.

g. Determine the annual Facility-related Dose at each monitored location.
i. Sum the annual MDD[3] and the annual baseline background dose rate.
ii. Subtract the sum from the normalized annual field dose to determine the annual facility-related dose.
iii. Identify any detectable facility-related dose (e.g., exceeding ~10 mrem during the annual period).

5. Quality Assurance

The quality assurance methods described in ANSI/HPS N13.37 are suitable methods of performing quality assurance. In summary, there should be:

- End-user quality assurance checks/measures

[3] The annual MDD is less than the sum of the quarterly MDD's since the statistics are better.

- Annual audits of the end-user by independent assessors
- Annual blind spike testing
- Triennial audits of the processor

Note: a processor laboratory accreditation program may be needed if the results of the quality assurance program routinely identify unsatisfactory results.

6. Data Reporting

Report environmental data and analyses in accordance with Technical Specifications (e.g., in accordance with the Offsite Dose Calculation Manual).

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide.

Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged**.** Backfit and issue finality considerations do not apply to licensees and applicants under 10 CFR Part 20.

REFERENCES

1. Environmental Protection Agency (EPA) 40 CFR 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."[4]

2. *Title 10 of the Code of Federal Regulations* (10 CFR), Part 20, "Standards for Protection against Radiation," U.S. Nuclear Regulatory Commission, Washington, DC 20555.[5]

3. 10 CFR Part 50, General Design Criterion 64, "Monitoring Radioactivity Releases," of Appendix A, "General Design Criteria for Nuclear Power Plants."

4. American National Standards Institute (ANSI) N545 (1975) "Performance, Testing, and Procedural Specifications for Thermoluminescence Dosimetry (Environmental Applications)."[6]

---

[4] Copies of EPA Library Services may be obtained through their Web site: http://www.epa.gov/libraries/library_services.html.

5 Publicly available NRC-published documents are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail pdr.resource@nrc.gov.

[6] Copies of American National Standards Institute (ANSI) documents may be purchased through their Web site at: http://webstore.ansi.org/.

5. American National Standards Institute/Health Physics Society (ANSI/HPS) N13.37 - 2014, "Environmental Dosimetry – Criteria for System Design and Implementation."[7]

6. Regulatory Guide 4.1, "Radiological Environmental Monitoring for Nuclear Power Plants."

7. Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactive Material in Liquid and Gaseous Effluents and Solid Waste."

8. International Standard IEC 62387, "Radiation Protection Instrumentation – Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation."

Appendix A

Plain Language Definitions (see also ANSI/HPS 13.37)

Accuracy: A measure of the difference between the measured value and the conventionally true value (expressed either as the standard deviation or as the coefficient of variation (also referred to as the bias)).

Coefficient of Variation (CV): The standard deviation (of a series of measurements) divided by the mean value of the measurements.

Baseline background dose (B_Q or B_A): The average background radiation dose based on historical averages.

Bias: The mean deviation from the conventionally true value (expressed as a fraction of the conventionally true value).

Conventionally true value (D): The best estimate of the delivered radiation dose.

Extraneous dose: The extra dose accumulated on a dosimeter prior to and after field deployment.

Facility-related dose (F_Q or F_A): The dose from radiation originating from the monitored facility.

Mean: The arithmetic average.

Minimum differential dose (MDD_x): The smallest amount of facility-related dose that can be reliably detected.

Performance Quotient (P): A measure of the accuracy in spiked dosimeter testing. The P value is calculated as the spiked dosimeter reading. minus its spiked dose, divided by its spiked dose. The average P value should not exceed 0.15 for the set of spiked dosimeters.

[7] Copies of American National Standards Institute /Health Physics Society (ANSI/HPS) documents may be purchased through their Web site at: http://webstore.ansi.org/ or through HPS Web site at http://www.hps.org.

Precision: The variation of measured values around its mean measured value (expressed quantitatively as either the standard deviation or as the coefficient of variation).

Standard deviation S_x: The average variation in a series of measurements, calculated as:

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

$$\textbf{where} \quad \bar{x} = \frac{1}{N} \cdot \sum_{i=1}^{N} x_i$$

and

$\mathbf{N}$ = **the number of test results**

$\mathbf{x_i}$ = **the values of the test results**

Transit dose: The dose received by a field dosimeter when not deployed in the field. This occurs from the time of annealing to the time the dosimeter is deployed in the field, and from the time the dosimeter is removed from the field to the time the dosimeter is processed. Transit dose does not include storage dose during field deployment.