## • Technical Guidelines for Personnel Dosimetry Calibrations

A base of technical information has been acquired and used to evaluate the calibration, design, and performance of selected personnel dosimetry systems in use at Department of Energy (DOE) facilities. A technical document was prepared to guide DOE and DOE contractors in selecting and evaluating personnel dosimetry systems and calibrations. A parallel effort was initiated to intercompare the radiological calibrations standards used to calibrate DOE personnel dosimeters.

TECHNICAL GUIDELINES FOR PERSONNEL DOSIMETRY CALIBRATIONS

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The purpose of this project is to assemble information to guide DOE and DOE contractors in selecting personnel dosimetry systems and calibrations and to initiate an intercomparison of calibration standards among DOE laboratories. Personnel dosimetry performance is strongly influenced by dosimeter calibration techniques. Proper calibration assures that the response of a personnel dosimeter correlates with the radiation dose equivalent received by an individual. Errors and uncertainties arising in the calibration are propagated through the entire personnel dosimetry system, often causing incorrect assessments of radiation dose equivalents to personnel. The design of the dosimeter influences its performance at energies far from the chosen calibration points. The correct interpretation of the dosimeter response is important for an accurate assignment of dose equivalent for exposures received in the work environment.

This project is divided into three tasks. The first task was to compile a data base on the performance of personnel dosimetry systems currently used by DOE laboratories. The second task was to prepare a set of guidelines for the performance, design and calibration of personnel dosimetry systems. The third task was to prepare for the intercomparison of calibration standards scheduled to begin in early FY 1983.

- The Performance of DOE Personnel Dosimetry Systems

A set of tests was performed based on those specified in the American National Draft Standard, Criteria for Testing Personnel Dosimetry Performance, ANSI N13.11 (ANSI 1978). Tests in addition to those specified were performed to provide information on energy response and radiation mixture response of the dosimeters. Eleven DOE laboratories participated in the tests.

Dosimeters were shipped to PNL for exposures to random levels and returned for readout. In phase I, the tests were patterned after those specified in ANSI N13.11 (ANSI 1978), using participant calibrations. Calibration information from PNL was supplied for Phase II, and the data were re-evaluated. Additional testing not specified in ANSI N13.11 was performed in Phase III. The results for Phases I and II were included in the annual report for FY 1981. Below we discuss results for Phase III.

Irradiation categories for x rays ranged in effective energy from 16 keV (k-fluorescent technique) to 167 keV (heavily-filtered technique). In Figure 1 the fractional difference between the reported and the given doses (bias) is plotted versus the x-ray technique in ascending order of effective energy for dosimeters using thermoluminescent (TLD) material. The open squares represent calibration points provided by PNL. The closed circles represent the response for systems that use one fixed calibration constant for all photon energies. The open circles represent the response of dosimetry systems using variable-response functions. variable-response systems use ratios of element responses as a basis for adjusting reported dose. The variable-response techniques provided superior performance

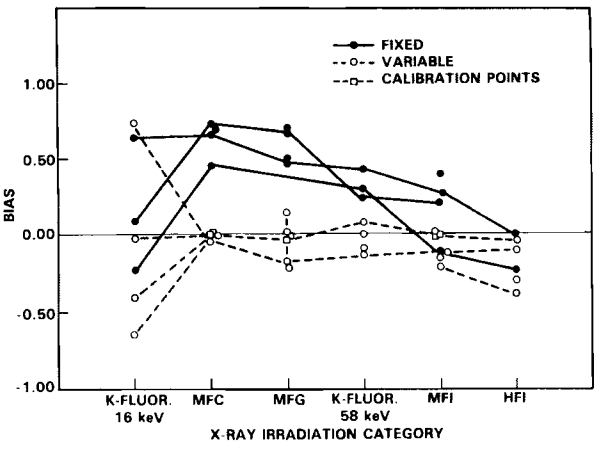


**FIGURE 1.** X-Ray Shallow-Dose Performance of TLD Dosimeters. The dosimetry systems were calibrated using PNL irradiations.

characteristics. The fixed-response technique did not have the flexibility to improve performance at x-ray energies without compromising performance for beta and $^{137}Cs$ categories. The performance of 16-keV x-ray irradiations was poor, varied widely, and was not related to dosimeter type. Processors with both fixed and variable calibration TLD dosimeters had difficulty interpreting the shallow-dose response to 16-keV x rays.

Performance of the film dosimeters is shown in Figure 2. Interpretation of dose

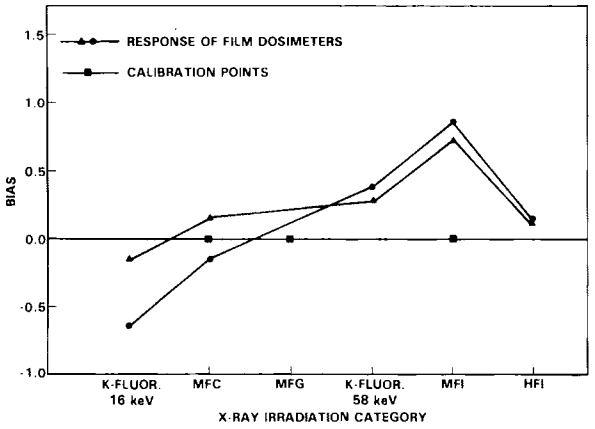


**FIGURE 2.** X-Ray Shallow-Dose Performance of Film Dosimeters. The dosimetry systems were calibrated using PNL irradiations.

from film is more difficult than for TLDs because film density varies with both photon energy and magnitude of delivered dose. The usefulness of the calibration irradiations provided by PNL was limited because only one dose level was provided for each energy. The x-ray performance for the film dosimeters was generally poorer than for both fixed and variable dosimeters was difficult to control because of the energy and dose-level dependence of the film.

The low-energy beta response for each dosimeter was determined from exposures to $^{85}Kr$ (0.67 MeV maximum energy) and $^{90}Sr/^{90}Y$ (2.3 MeV maximum energy) sources. The response per unit delivered dose of $^{85}Kr$ was divided by the response per unit dose of $^{90}Sr$ and plotted as a function of open window thickness (Figure 3). The lowest response was observed for TLD elements 230 mg/cm$^2$ in mass thickness (0.9 mm). Dosimeter response decreased with increasing filtration over the "shallow dose" TLD. The best response, 70%, was achieved for a TLD element 15 mg/cm$^2$ in mass thickness using minimal filtration.

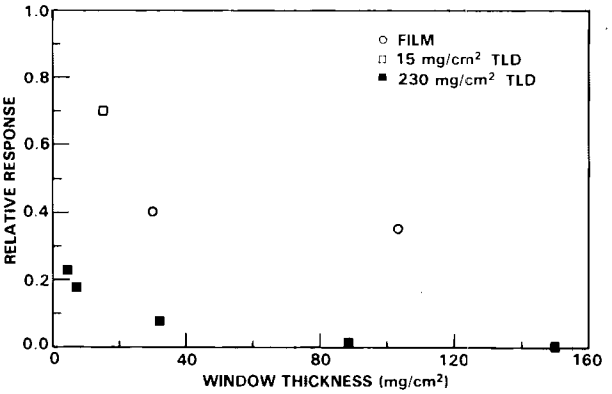


**FIGURE 3.** Low-Energy Beta Response [$^{85}Kr/^{90}Sr$-$^{90}Y$].

Film data were sparse; however, the low-energy beta response was superior to the response of thick TLDs.

The effect of neutron calibration facility size on TLD-albedo dosimeter response was investigated. The effective room radius for each facility was calculated based on room dimensions. When the facility provided only one scatter surface (e.g., an outdoor calibration range or metal building with concrete floor), the effective room radius that would yield the same amount of scatter in an enclosed room was estimated. The relative scatter component increases with the source-to-phantom distance, so that all room radii were normalized to represent the scatter conditions for an irradiation distance of 50 cm. Formulas for room scatter are found in NBS Special Publication 633 (Schwartz and Eisenhauer 1982). The room return calculations are only a general guideline, since the scatter conditions are influenced by other factors not taken into account. Results are shown in Figure 4. In general, the bias approaches zero for large room radii (low scatter). High-scatter facilities result in low dosimeter response.

In summary, the performance data indicated that:

-- the best performance at x-ray energies was achieved by TLD dosimeters using response algorithms dependent on a measured estimation of mean energy (variable-response dosimeters);

-- the response of dosimeters using film packets was difficult to calibrate and control at x-ray energies;

-- thinner sensitive elements are required for adequate response to low-energy beta sources;

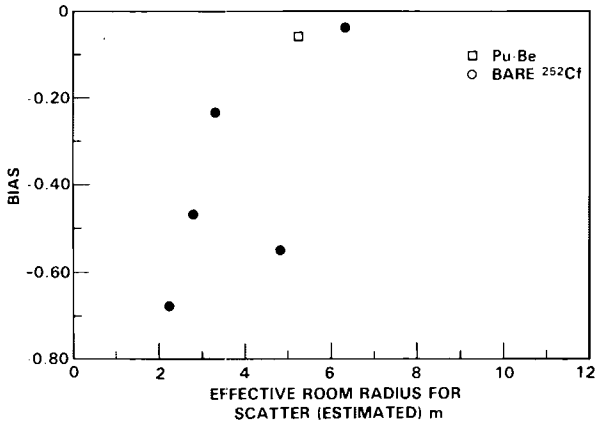


**FIGURE 4.** TLD-Albedo Dosimeter Performance as a Function of Effective Irradiation Room Radius. The effective room radii were adjusted to represent relative scatter contribution at 50 cm.

-- the calibration of TLD albedo dosimeters varies widely and depends on the size of the calibration facility.

- Guidelines for the Calibration of Personnel Dosimeters

A set of guidelines was prepared for the performance, design and calibration of personnel dosimetry systems using the dosimetry performance data base developed in Phase I. The guidelines are closely related to ANSI N13.11 (ANSI 1978); however, instead of specifying test arrangements they list recommended performance criteria, dosimeter design parameters and calibration techniques. The performance criteria are based on recommendations by the International Commission on Radiation Units and Measurements and the National Council on Radiation Protection and Measurements. The irradiation categories include those specified in ANSI N13.11. Important additions address the problems observed in the development of the data base on dosimeter performance. Additional x-ray, beta-particle and neutron categories were added. The guidelines for dosimeter design stressed avoidance of poor performance due to design limitations.

The guidelines for dosimeter calibrations specified a set of radiation fields and geometries intended to standardize reference calibrations. They follow ANSI N13.11 where practical.

- Intercomparison of Radiological Calibration Standards

A program for dosimetry intercomparisons among major DOE laboratories has been initiated to demonstrate the capabilities of putting into place improved and more uniform calibration methods. This program will also help stimulate communications between the laboratories.

The method for this intercomparison will be to ship a set of instruments calibrated at PNL to participating DOE laboratories. Each laboratory will report the instruments' response per unit exposure or dose delivered by x-ray source(s), a $^{137}Cs$ or $^{60}Co$ source, beta source(s), and neutron source(s). The responses measured at each laboratory will be compared to those measured at PNL. The instruments will include ionization chambers, a G-M counter, cables, and an electrometer with built-in power supply. The calibration of these systems is ongoing and will be completed within the first quarter of FY 1983.

In addition to the above, a set of TLDs will be shipped to the DOE laboratories, exposed, and returned to PNL for evaluation.

REFERENCES

American National Standards Institute (ANSI). 1978. Draft American National Standard Criteria for Testing Personnel Dosimetry Performance. ANSI N13.11, New York, New York.

Schwartz, R. B., and C. M. Eisenhauer. 1982. "Procedures for Calibrating Neutron Personnel Dosimeters." NBS Special Publication 633, National Bureau of Standards, Washington, D.C.