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ACCURACY OF EXTERNAL PERSONNEL DOSIMETRY SYSTEMS IN MIXED NEUTRON AND GAMMA RADIATION FIELDS*

R. E. Swaja

Health and Safety Research Division
Oak Ridge National Laboratory,†
Oak Ridge, Tennessee, USA 37830

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Estimates of biological effects associated with exposure to external radiation fields are generally based on the measured response of passive personnel dosimetry systems to the incident radiation. The increasing number of persons occupationally exposed to mixed neutron and gamma fields and recent questions concerning the relative biological hazards of different types of radiation have emphasized the need for accurate personnel radiation dose measurements. To determine the performance characteristics of various neutron and gamma personnel dosimetry systems under actual mixed-field conditions, seven annual dosimetry intercomparison studies[1,2] have been conducted since 1974 at Oak Ridge National Laboratory using the Health Physics Research Reactor (HPRR)[3]. These studies have produced more than 2000 measurements of neutron and gamma dose equivalents between 0.1 to 15.0 mSv on anthropomorphic phantoms in six different radiation fields.

Participants in these studies generally used one of four basic types of neutron dosimeters - nuclear emulsion film, thermoluminescent (TLD), TLD-albedo, and track-etch. Table 1 shows the mean of normalized (measured divided by reference) dose equivalents averaged over the seven intercomparisons for each basic neutron dosimeter type and each radiation field (HPRR plus shield) used in these studies. Mean values of the dose equivalents measured with film dosimeters are less than 77% of reference doses for all spectra with some individual measurements indicating zero dose. Thermoluminescent and TLD-albedo dosimeters yield similar qualitative performance in that the mean normalized dose increases monotonically with increasing neutron spectral softness (i.e., decreasing median energy). For the softest neutron spectrum (Lucite/concrete shield), average measured dose equivalents are factors of 3.42 and 1.94 times reference values for TLD and albedo dosimeters, respectively. Individual measurements were higher than reference dose equivalents by as much as a factor of 10 for TLD's and 3 for albedo dosimeters. Average measurement accuracies exhibited by track-etch dosimeters were within 0.60 to 0.97 times reference values for all spectra. However, several individual measurements using various track detection methods and materials indicated zero dose.

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Table 1. Average normalized neutron dose equivalents for the basic dosimeter types used in the personnel dosimetry intercomparison studies

Shield	Neutron median energy	Neutron dosimeter type			
		Film	TLD	TLD-albedo	Track
None	0.78 MeV	0.41	0.75	0.91	0.82
13-cm steel	0.34 MeV	0.77	-	1.41	0.97
Steel/concrete	6.0 keV	0.15	-	1.42	0.75
20-cm concrete	3.3 keV	0.18	1.47	1.51	0.60
12-cm Lucite	68 eV	0.65	2.35	1.54	0.87
Lucite/concrete	10 eV	0.28	3.42	1.94	0.70

Gamma dose equivalents determined during the intercomparisons were measured using TLD or film systems. Thermoluminescent dosimeters with low neutron sensitivity (primarily ^{7}LiF or $CaSO_4$) yielded average dose equivalents between 0.84 and 1.16 times reference values for all spectra. Film gamma dosimeters yielded average results which were higher than TLD-measured values by as much as a factor of 1.46. Results of individual measurements using natural LiF dosimeters, which are very sensitive to neutrons, produced some reported gamma dose equivalents which were more than a factor of 100 higher than reference values.

Analysis of these results indicates that significant inaccuracies can occur in neutron and gamma dose measurements in mixed radiation fields unless dosimeter performance and characteristics of the monitoring environment are considered in dosimeter evaluation. Neutron dose measurement accuracies could be improved by using dosimeters more suited to the anticipated radiation fields, calibrating dosimeters with sources appropriate for the energy spectra to be measured, applying correction factors to account for dosimeter performance in incident radiation fields, and standardizing the basis of reported dose equivalents. With regard to gamma monitoring, intercomparison results indicate that the selection of a basic dosimeter type which is relatively insensitive to neutrons is of great importance for accurate dose measurements in mixed fields.

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