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A New Technique to Improve the Accuracy of Albedo Neutron Dosimeter Evaluations

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A New Technique to Improve the Accuracy of Albedo Neutron Dosimeter Evaluations*

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Introduction

The calibration factor for albedo neutron dosimeters varies greatly depending upon the energy of the neutrons in the exposure. It has been found that, under some scattering conditions, the calibration factor can be determined by using a ratio of the thermal and fast neutron dose rates. In a previous study, we used the PNR-4 9-in. sphere remmeter to study the relationship between the calibration factor for albedo neutron dosimeters and the thermal neutron component of the dose.[1] We found that the relationship between the percent thermal and the calibration factor varied greatly in operational areas. Therefore, the calibration factor could not be determined from the incident thermal neutrons.

We review here results obtained over an eight-year period at each Lawrence Livermore National Laboratory facility where neutron exposure may occur. When each facility is considered separately, we find there is a stronger relationship between the ratio of the readings of the 9-in. to 3-in. spheres (9/3 ratio) and the "percent thermal" (percent of total neutron dose contributed by thermal neutrons) than we had expected to exist. With this relationship confirmed, we then review our dosimeter readings from personnel and albedo badges and find that the readings are consistent with the use of a calibration factor for the albedo dosimeter which varies with changes in the ratio of the personnel and albedo dosimeter TLD readings. We find significant improvement in our personnel exposure estimates by applying these variable calibration factors in place of the single value used previously. It is still necessary to know in which facility the person was working when exposed; but, for most of the LLNL exposures, only two sets of calibration factors are required.

Results From Field Surveys With Instruments

We plotted results obtained from neutron surveys over an eight-year period to show the 9/3 ratio as a function of "percent thermal." We had plotted the results from each building or facility separately, but found that the results from several of these facilities can be combined for purposes of dosimeter evaluations (Fig. 1). The calibration factor for the albedo neutron dosimeter (right ordinate of Fig. 1) increases as the percent thermal increases.

Not all the results from the buildings or facilities (at LLNL we use building numbers for identification) fell along the solid line seen in Fig. 1. In Fig. 2, we show the results obtained at the Bldg. 231 plutonium storage vault. Inside the vault there is a lower thermal neutron component for a given 9/3 ratio and all the data points fall below the solid line. The data obtained from outside the vault, however, again fall close to the solid line. The low thermal component observed inside this vault results from the large room. When a neutron source is placed in a room, the thermal neutron fluence is fairly constant throughout the room, but the magnitude of this fluence is a function of room size, with smaller rooms having higher fluences. Therefore, in a small storage vault such as the Bldg. 332 vault, the percent thermal at a given 9/3 ratio is higher than the percent thermal in a large storage vault such as Bldg. 231 (Fig. 2).

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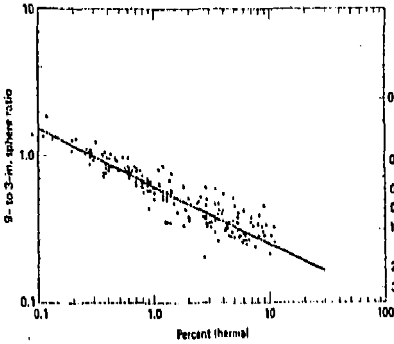

Fig. 1. The ratio of the 9/3-in. spheres as a function of the percent thermal (percent of the total neutron dose rate delivered by thermal neutron) for several LLNL facilities.

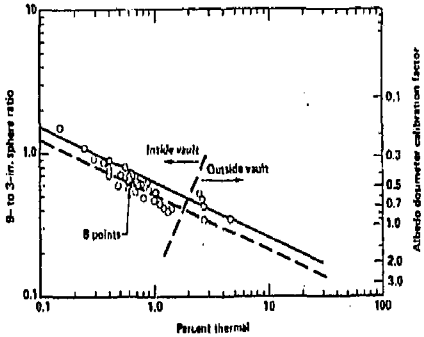

Fig 2. The ratio of the 9/3-in. spheres as a function of the percent thermal at the Bldg. 231 plutonium storage vault.

Figure 3 shows the results for Bldg. 233, which is a neutron-source storage area. The points fall above the solid line taken from Fig. 1, indicating a higher average thermal neutron component than was found at the other facilities. Because the room is large, we would expect the results to fall below the curve, but the neutron sources are stored in concrete, polyethylene, or paraffin shielding which thermalize the neutrons. Each of these shields then becomes a source of thermal neutrons, which causes the observed increase in the thermal neutron component throughout the room.

The thermal neutron component, from a source located outside a building, is lower than if the source were in a room. Figure 4 shows the results obtained at Site 300 in the area around the LINAC (target is outside), where the data points fall below the line.

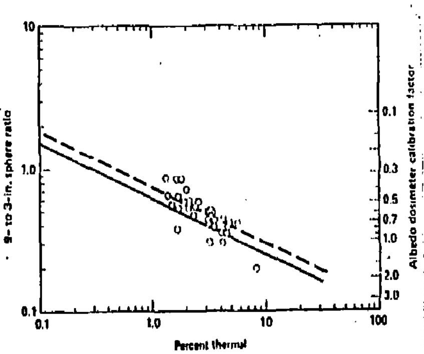

Fig. 3 The ratio of the 9/3-in. spheres as a function of percent thermal at the Bldg. 233 neutron source storage vault.

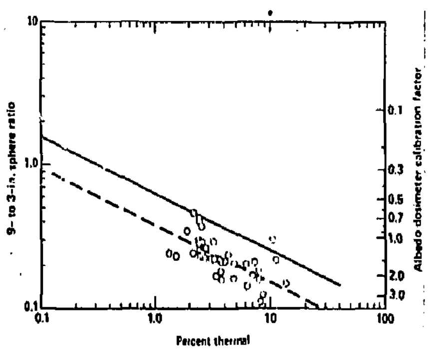

Fig. 4 The ratio of the 9/3-in. spheres as a function of the percent thermal in the vicinity of a LINAC.

We had again confirmed there is no constant relationship between the 9/3 in. sphere ratio (and corresponding albedo calibration factor) and the percent thermal for all exposure conditions. However, we found that, for neutron exposures occurring at all of our facilities (except the reactor), there is a definite relationship and the spread of the data points around the line drawn on each of the figures is fairly small. Therefore, a ratio of the readings of the TLDs in the albedo dosimeter to the readings of the thermal neutron sensitive TLD in the personnel badge can be used to approximately determine the albedo neutron dosimeter calibration factor if the facility in which the exposure occurred is known.

Dosimeter Response

We can calculate the expected TLD readings of the personnel and albedo dosimeters from Figs. 1 through 4. The reading of the TLD 600s in the albedo dosimeter is primarily from the "intermediate energy" albedo neutrons. The reading also contains what normally is a small contribution from the incident intermediate energy neutrons and incident and reflected thermal neutrons. The size of the albedo TLD reading is proportional to the "Albedo Dosimeter Calibration Factor" given on the right-hand scale of the figures. For example, if the albedo calibration factor is one, the reading from the TLD 600 would be 1R for a neutron dose equivalent of 1 Rem.

The neutron reading of the TLD 100 in the personnel badge is more complex. The largest part of the reading, when used in field application, will normally be from the incident and reflected thermal neutrons. It also responds to the incident and albedo intermediate energy neutrons which are detected by the albedo dosimeter. In addition, since it is not surrounded by cadmium like the TLD 600 in the albedo dosimeter, it also responds to the "thermal" albedo neutrons. Its response to these neutrons is $\sim$1.6 times the intermediate energy response of the albedo dosimeter, giving a total sensitivity 2.26 times that of the albedo dosimeter. A further complication is that the response of the TLD 100s is about half the response of TLD 600s to neutrons.

Using the above information, we have calculated the expected relative reading of the TLD 600s in the albedo dosimeter and the TLD 100s in the personnel badge. The lines drawn in Figs. 5 and 6 are based on these calculations and show the albedo calibration factors. Plotted on Fig. 5, are data from badges worn by persons working in one of our facilities where we know the albedo calibration factor that should be applied to the TLD readings. When we compare the known factor determined by observing the workers' actions with those derived from the location of the points on Fig. 5, we find good agreement, confirming the accuracy of this technique.[2]

Results from other buildings are shown in Fig. 6. In most cases, when the calibration factor that existed at the worker's location was known, that point on the figure is in agreement with the calibration factors derived from the lines.

Routine personnel exposures can be evaluated using a table showing the ratio of the albedo dosimeter and bare TLD 100 readings and the corresponding albedo calibration factor for each facility.[2] Since TLD measurements are subject to anomolies and uncertainties in their readings, we require that the observed ratios from the TLDs be within the extremes known to exist in the work area. A procedure for handling anomolies, questionable TLD readings, and readings where only one dosimeter indicates an exposure needs to be developed.

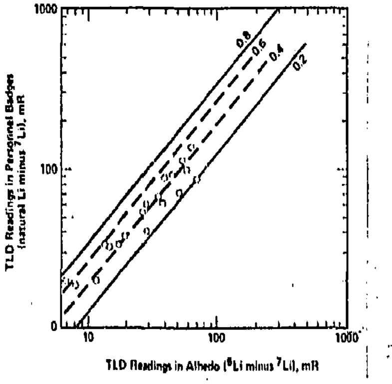

Fig. 5. Results from personnel dosimeters and albedo badges worn by personnel at one of our facilities. The lines correspond to several albedo dosimeter calibration factors.

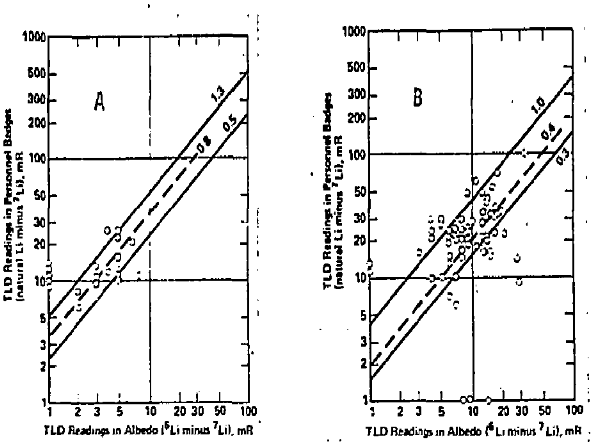

Fig. 6. Results from personnel dosimeters and albedo badges worn by (A) custodians in a radiochemistry building, and (B) personnel at our Bldg. 332 plutonium vault. The lines correspond to several albedo dosimeter calibration factors.

References

1. Hankins, D.E., "The Effect of Energy Dependence on the Evaluations of Albedo Neutron Dosimeters," Proceedings of the Ninth Midyear Topical Symposium on Operational Health Physics, Denver, CO, p. 861 (1976).

2. Hankins, D.E., Evaluation of Albedo Neutron Dosimeters Using the Ratio of TLD Readings in Personnel and Albedo Badges, Lawrence Livermore National Laboratory Report, UCID-in publication (1983).

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