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PERSONNEL NEUTRON DOSIMETRY AT SLAC*

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ABSTRACT

The rationale and methods of the personnel neutron dosimetry system used at SLAC are presented and discussed.

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At SLAC, more than 90% of the recorded personnel doses are caused by photon radiation, and consequently neutron exposures are a minor problem. SLAC has a program of personnel dosimetry using ^{6}LiF/^{7}LiF TLD dosimeters. These are Teflon disks that are incorporated in a wallet identification card. No moderation is provided, other than that afforded by the body of the wearer. Approximately 200 SLAC employees are classified as Radiation Workers, and their dosimeters are read quarterly. Most of these individuals are issued one disc each of ^{6}LiF and ^{7}LiF. A few individuals are given dosimeters with several of each disc, to provide additional precision in subsequent dose assessment. The remaining SLAC employees (about 1000) are issued an "accident dosimeter" that is read annually. Visitors, both long and short-term, are also provided with an accident dosimeter (400-500 each year).

Doses imparted to individuals tend to be significantly smaller when the accelerator is operating. The largest doses are actually imparted during down times when repair and maintenance work is done near activated components. All components of the radiation field are small in the occupied areas during periods of operation, even in the Research Area, and this is the only time when neutron exposure rates would be present.

The significant sources of neutron radiation are located in the Research Area: End Stations A, B, C, as well as SPEAR. Neutrons are produced by the giant-resonance nuclear photoeffect(1) and by higher energy photonuclear processes (predominantly from pion photoproduction(2)). For shield thicknesses greater than about two feet of concrete, the higher energy neutrons will have reached an equilibrium spectrum(3). In the Research Area, we make the assumption that this equilibrium spectrum is uniformly constant everywhere. Further, we assume that the ratio of thermal neutron flux to this fast neutron flux is constant wherever recordable neutron doses can be received.

There are no other neutron sources, apart from small PuBe sources for calibration purposes. Because the spectra of the sources is assumed to be uniform, and the neutron doses are historically small, we have been able to operate using a simplified dosimetry procedure. If we had multiple sources of neutrons of various types, or a history of large doses to individuals, we would be more interested in developing and using a "universal" neutron dosimeter.

The present system of neutron personnel dosimetry at SLAC is based on the following history. First, a calibration was performed by G. Svensson, in 1971[4], for thermal neutrons for the particular type of TLD material used at SLAC. Next, for fast neutron calibration, he exposed the ^{6}LiF material, backed by varying thicknesses of paraffin, to a PuBe source. He found that the response of the TLD increased rapidly as the paraffin backing thickness was increased, until thicknesses of about 1.5" were achieved. Thereafter the sensitivity was quite flat, out to at least 6". These results were consistent witn the sensitivity obtained for the same material at the center of a 4" diameter paraffin sphere.

Next, a series of experiments was performed in which a phantom consisting of a water-filled polyethylene cylinder of diameter 25 cm and height 40 cm was used. The TLD material was attached to this cylinder, which was rotated at a constant rate. This arrangement was exposed to PuBe and PuF sources in a tunnel where the ratio of fast to thermal fluxes could be varied over a range that encompassed the ratios measured at various locations in the Research Area. Within this range, the dosimeters proved to be sensitive only to the thermal flux already present: I.e., there was no change in response due to the presence of the water phantom, for fast/thermal flux ratios less than about 10.

The ratio of fast to thermal neutrons was determined at 8 locations around the Research Area at SLAC, extending over periods of more than one year. These determinations were made by using the ratio of simultaneously exposed moderated and unmoderated TLD dosimeters. These flux ratios ranged between 1 and 11, but most of the 32 individual ratios were clustered between 2 and 4. The average flux ratio for all determinations turned out to be 3.4. When converted to dose equivalent ratios, using the conservative assumption that the neutron quality factor is 10, the ratio of 110 rem (fast neutrons)/1 rem (thermal) is obtained.

In the SLAC program, we actually assume a ratio of 6 (rather than 3.4) for the fast/thermal fluences. Thus we are conservative by almost a factor of two in this parameter. In converting to dose equivalent in rem, a factor of 33 is employed. This is the ratio of fluence to dose-equivalent conversion factors at the two energies assumed: Thermal and the average energy of our fast neutrons, which is taken to be about 1.0 MeV. Thus to obtain a final dose assessment for an individual, we multiply the thermal dose assessment in rem by a factor of 200.

Actual information on the neutron spectrum at SLAC outside the shielding is very sparse. In a series of experiments using a proton recoil counter-moderated BF_3 counter combination, it was found that the average energy lay in the range 0.5 - 4.0 MeV. This overlaps the range of neutron energies found to be typical in experiments done at the various accelerator laboratories,[5] in which average energies are found in the range 0.2 - 8.0 MeV.

Although the neutron personnel dosimetry problem is mainly of academic interest to us, more accurate information on the neutron energy spectrum outside the shielding would be useful. This would be of value mainly in assessing the population dose equivalent, rather than for personnel dosimetry.

REFERENCES

1. See, for example, Evans Hayward, "Photonuclear Reactions," NBS Monograph 118, U.S. National Bureau of Standards, Washington D.C., 1970.

2. See, for example, H. Wade Patterson and Ralph H. Thomas, "Accelerator Health Physics," Ch. 3, pp 114-117, "New York and London, Academic Press), 1973.

3. W. S. Gilbert, D. Keefe, J. B. McCaslin, H. W. Patterson, A. R. Smith, L. D. Stephens, K. B. Shaw, G. R. Stevenson and R. H. Thomas, "1966 CERN-LRL-RHEL Shielding Experiment at the Cern Proton Synchrotron," UCRL-17941, UC-28, TID-4500 (53rd Ed.), 1968.

4. Göran Svensson, private communication, Stanford Linear Accelerator Center, Stanford, California, 1971.

5. See, for example, G. Bathow, U. Clausen, E. Freytag and K. Tesch, "Skyshine Measurements and Their Comparison with Estimates from Diffusion Theory," Deutsches Elektronen-Synchrotron, Hamburg, Report No. DESY 66/3 (1966).