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MODERATED NEUTRON SOURCES FOR CALIBRATING NEUTRON DOSIMETERS FOR REACTOR ENVIRONMENTS*

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1. Introduction

Neutron dosimeters used around reactor environments are often calibrated with (α, n) sources or ^{252}Cf sources. Since these sources emit neutrons which are more energetic than those outside power reactors[(1)], the readings of dosimeters calibrated in this manner may be erroneous because of the variation in their energy response.

To produce calibration sources whose neutrons approximate those to be monitored, certain groups[(2,3)] have embedded sources in spheres of various materials. Recently, Environmental Measurements Laboratory (EML) has also decided[(4)] to have such "moderated sources" for calibration. The assemblies chosen are spheres of polyethylene, 20.3 cm and 45.7 cm in diameter which can be enclosed by Fe shells 10.2 cm thick. The center of these assemblies has a cavity 1.2 cm in diameter containing a ^{252}Cf source 0.8 cm in diameter. This paper discusses the calculation of leakage spectra for these 4 assemblies.

2. Calculational Methods

The calculations were made with a modified version of the 05R Monte Carlo code and the ANISN discrete ordinates code, using nuclear data extracted from the ENDF/B IV library with appropriate ancillary programs.

In the Monte Carlo calculations, the region from 0.4 eV to 20 MeV

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was divided into 800 groups while the region below 0.4 eV was treated as one thermal group. Since the treatment of thermal neutrons is very time-consuming, the computation of thermal and "above-thermal" neutrons were performed separately. The latter used 800,000 source neutrons while the thermal fluence was obtained with 16,000 or 32,000 source neutrons. These were sampled from a Maxwellian distribution having a nuclear temperature of 1.42 MeV. In treating neutron interactions in CH_2 and Fe, anisotropic distributions were used for elastic scattering from C and Fe and for inelastic scattering to their lowest excited states. All other scattering, including that to 19 discrete levels in Fe, was assumed to be isotropic.

The ANISN calculations were made in the P_3S_{16} approximation using 100 energy groups and completely symmetric quadrature sets which satisfy even moment conditions. For each assembly, results were obtained for 20 and 100 mesh points using both "linear" and "step" approximations in the solution of the finite-difference form of the transport equation.

Results and Discussions

The neutron spectra at the surface of the assemblies, calculated by Monte Carlo, are shown in Fig. 1. The thermal fluences are also given in the figure.

Fig. 2 shows the ANISN results obtained with 100 mesh points and linear approximation. The thermal fluences are in good agreement with the Monte Carlo results. Qualitatively, the spectra appear also to be in good agreement. However, closer examination reveals that, in the region above 3 MeV, the ANISN curves fall more steeply than those in Fig. 1. This is most serious in the bottom curve where the high-energy fluences are only about one-half of those computed by Monte Carlo.

To determine the cause of this discrepancy, further Monte Carlo calculations were made with various anisotropic scattering successively assumed to be isotropic. With these simplifications, the computed spectra approached those by ANISN and when all scattering was made isotropic, the resulting fluences in the high energy region were lower than those by ANISN.

4. Conclusions

Leakage spectra for 4 moderated source assemblies intended for calibrating neutron dosimeters for reactor environments have been computed using Monte Carlo and discrete ordinates methods. The results by the two different computational methods are in reasonable but not perfect agreement. Since the spectra calculated by Monte Carlo were made with more detailed treatment of neutron interactions, they are believed to be the more accurate and the discrepancies in the ANISN results are attributed to inadequate treatment of anisotropic scattering.

References

1. F. Hajnal, R. Sanna, R. M. Ryan and E. Donnelly, "Stray Neutron Fields in the Containment of PWR's" in Proc. Intern. Sym. on Occupational Radiation Exposure in Nuclear Fuel Cycle Facilities, (IAEA, Vienna, 1979). Paper IAEA-SM-242/24.

2. R. V. Griffith, D. E. Slaughter, H. W. Patterson, J. L. Beach, E. G. Frank, D. W. Rueppel and J. C. Fisher, "Multi-technique characterization of Neutron Fields from Moderated ^{252}Cf and ^{238}Pu-Be Sources" in Proc. National and International Standardization of Radiation Dosimetry, (IAEA, Vienna, 1978) Vol. II, p. 167.

3. R. B. Schwartz, "The Design and Construction of a D_2O - Moderated ^{252}Cf Source for Calibrating Neutron Personnel Dosimeters Used at Nuclear Power Reactors", Report to U.S.N.R.C. No. NRC-01-78-012 (November, 1979).

4. F. Hajnal, private communication (September, 1978).

Figure Captions

Fig. 1. Leakage neutron spectra, calculated by Monte Carlo, for ^{252}Cf moderated source assemblies. The assemblies are: (a), 20.3 cm diameter CH_2; (b), 45.7 cm diameter CH_2; (c), 20.3 cm diameter CH_2 + 10.2 cm Fe; (d), 45.7 cm diameter CH_2 + 10.2 cm Fe. The spectra are plotted as fluence per logarithmic energy interval and are displaced vertically by the indicated factors. The values in parenthesis are the thermal fluence ($<$ 0.4 eV) per source neutron.

Fig. 2. Results for the 4 moderated source assemblies calculated by ANISN. The notations are the same as in the previous figure.

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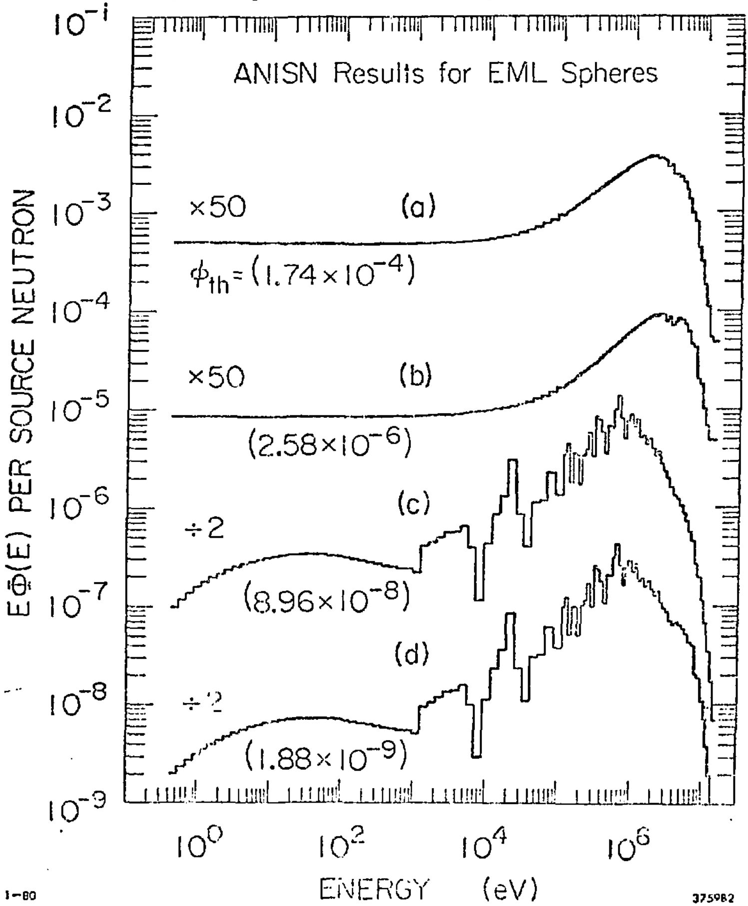
Please replace Figure 2 with the following corrected Figure 2.



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