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EFFECT OF HYDROGENOUS SHIELDS ON THE AVERAGE ENERGY OF NEUTRON SPECTRA*

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In a previous work[1], the authors and colleagues studied problems of photoneutron transport in concrete rooms using the Monte Carlo transport program, MORSE[2] and supporting experimental measurements. From this work, an empirical method of calculation was developed based on the average energy, $\bar{E}$, of the neutron spectrum. This method has been described in NCRP 79[3]. Using this method, it is possible to calculate the effect of metal shielding and also scattering inside a concrete room based on $\bar{E}$,and to provide a suitable conversion factor for converting fluence to either dose equivalent or to absorbed dose. For subsequent shielding, TVL's for polyethylene or concrete were given for two different geometries, one from the accelerator moderated by a heavy metal (sphere geometry) and the other from these same spectra modified by room scattering (long geometry). It should be noted that these TVL's are for shields where the thickness is great enough that there is an exponential decrease, and thus would overestimate attenuation in the first few centimeters (see, for example, Fig. 1). The neutron spectra used in this paper are as follows: 15W = photoneutrons from 15 MeV on tungsten, 25W = photoneutrons from 25 MeV on tungsten, Cf = ^{252}Cf and 14W4W = photoneutrons from 14 MeV on tungsten surrounded by 4 inches (10 cm) of tungsten.

While the TVL's given in NCRP 79 are correct for a given $\bar{E}$, provided the shield is thick enough, they do not give any insight into how the average energy of the neutrons changes with depth in either concrete or polyethylene shields. It was felt that some such information would be informative, and is the subject of this paper.

When penetrating heavy elements, such as iron, lead or tungsten, the average energy of the neutron spectrum decreases nearly exponentially at first, and then approaches a constant value at large thicknesses. This is expected since the major mechanism for energy loss is through non-elastic scattering [inealstic, (n,2n), (n,p), etc.]. In hydrogenous materials, however, the energy loss in most energy ranges is dominated by elastic scattering on hydrogen nuclei. Thus, the macroscopic behavior may be quite different.

Using the MORSE code, we have studied photoneutrons penetrating heavy metals such as might be found in a medical accelerator, and then subsequently striking a concrete or polyethylene shield. These spectra have been used in two different geometries. The first is a spherically symmetric shield such as might be added around the accelerator head to reduce neutron fluence, or might be applicable to the accelerator room itself which has a direct view of the accelerator. The second geometry is that of a long tunnel or duct with the absorber at the end, representing the door at the outer end of a maze. In the former case, the neutron spectrum

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incident on the absorber is that from the accelerator (through the heavy metal shield) plus the room scattered neutrons. For this case, a range of values for $\bar{E}$ are of interest representing the different source terms. In the latter case, only room scattered neutrons reach the absorber. For this case, only a single value for $\bar{E}$ is needed since the $\bar{E}$ of neutrons reaching a door down a maze is always in the neighborhood of 100 keV regardless of the accelerator energy.

We have not found any simple empirical relations to describe the effect of hydrogenous shields on $\bar{E}$. Instead, we present some graphical data which should be of some help in analyzing measurements. The spherical geometry results are shown in Fig. 2 for concrete and Fig. 3 for polyethylene.

The graphs cover the range of thicknesses which might be required for medical accelerator shielding. From the figures, we note that there is always an initial decrease in $\bar{E}$ followed by a slow hardening of the spectrum with increasing depth in the shield. This is consistent with the removal of the lower energy neutrons early in the shield.

Figure 4 shows the average energy outside a polyethylene shield in a geometry such as a door into a maze. Again, we see the rapid decrease in the $\bar{E}$ followed by a gradual increase in $\bar{E}$. The attenuation of dose equivalent through such a door closely follows an exponential with the TVL's as given in NCRP 79. When using a fluence detector to determine neutron leakage through the door, it may be easier to measure with the door open and calculate the result with the door closed rather than try to correct for the effects of the changing spectrum through the door.

REFERENCES

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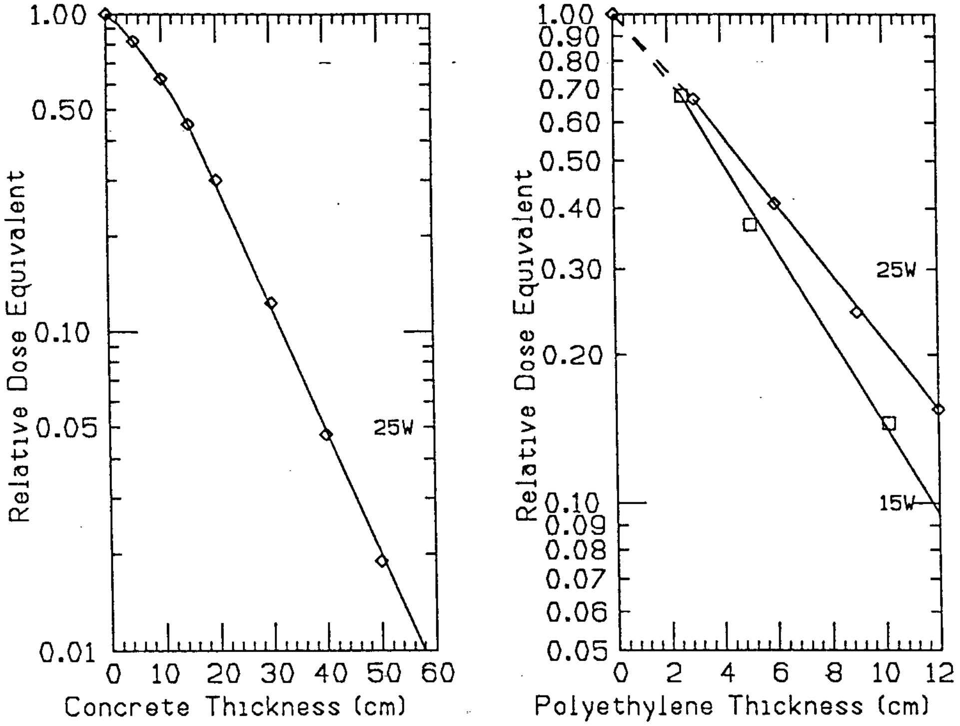

Figure 1. Transmission of 25W and 15W spectra through spherical shields.

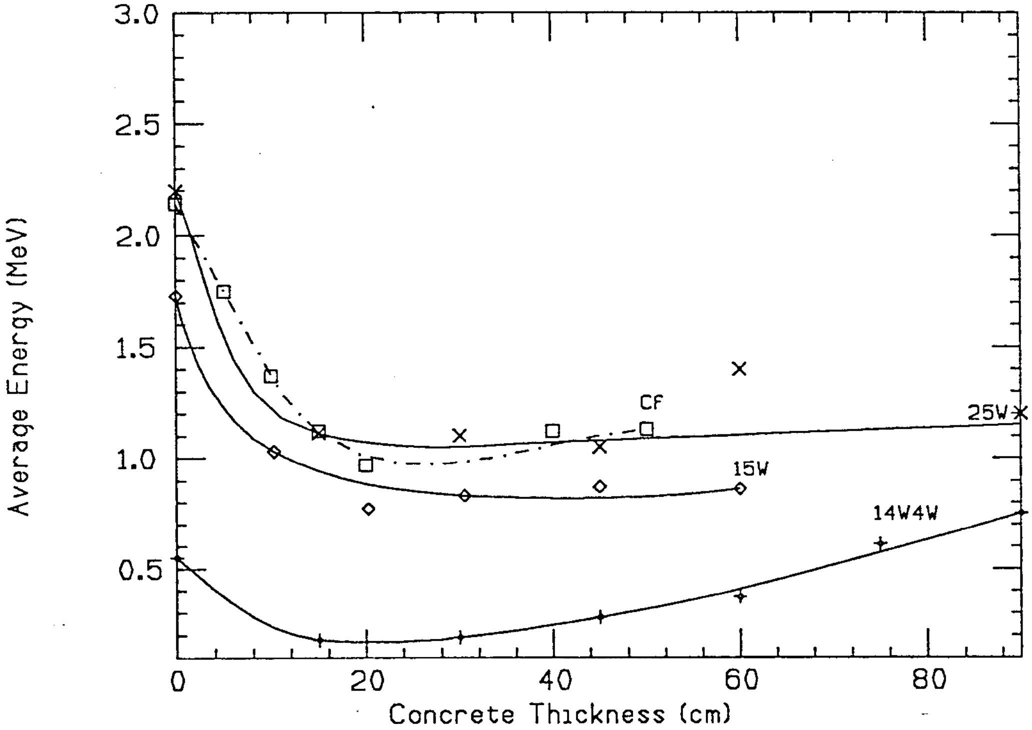

Figure 2. Average neutron energy through concrete.

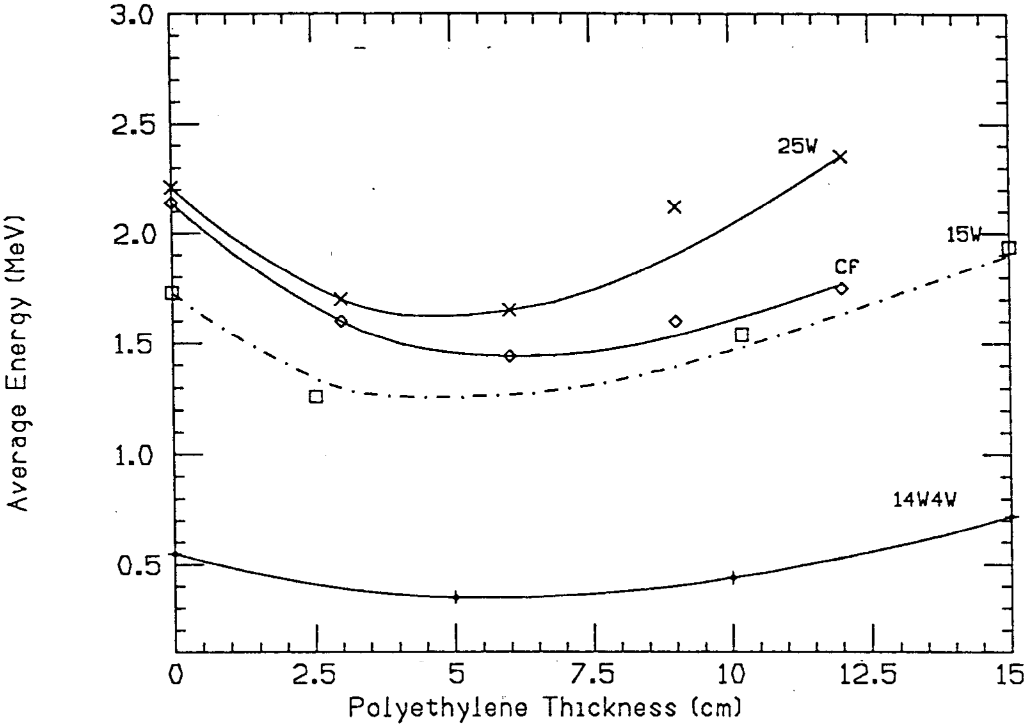

Figure 3. Average neutron energy through polyethylene.

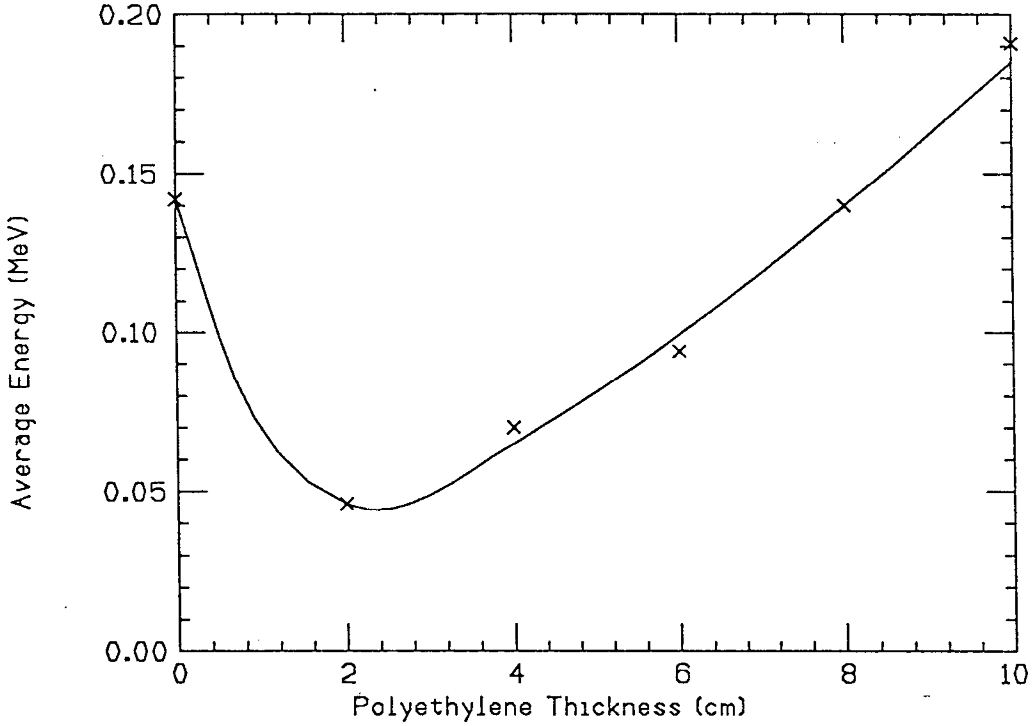

Figure 4. Average neutron energy in polyethylene for a scattered neutron spectrum ($\bar{E} = 140$ keV) as an input.