A PASSIVE FAST-NEUTRON SPECTROMETER-DOSIMETER BASED ON CR-39

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We describe here a new passive miniature fast neutron spectrometer-dosimeter. The device is based on the detection of proton tracks by electrochemical etching of CR-39 foils covered with thin polyethylene layers of different thicknesses. By means of this device it is possible to assess the fast neutron energy spectrum in 10 energy intervals in the energy range 0.5-15 MeV. Dose equivalents can be determined in the dose equivalent range 20 mRem to 8 Rem, approximately.

The device has been used by us for the evaluation of the photoneutron spectrum in the beam of a high-energy (16 MeV) medical linear accelerator (1). We anticipate the use of this system for the assessment of fast neutron spectra in fusion reactor blankets, for the experimental verification of isodose distributions in neutron radiotherapy and possibly as a personnel fast neutron spectrometer-dosimeter in high-energy accelerator facilities.

The miniature neutron spectrometer (MNS) is composed of a CR-39 foil (American Acrylics and Plastics, Stratford, Connecticut), ∿500μm thick, and polyethylene of various thicknesses in contact with it. The CR-39 foil detects recoil protons emitted from the radiators, due to elastic scattering of the incident neutrons with hydrogen nuclei in the polyethylene. A schematic diagram of the 27x27x0.5mm spectrometer is shown in Fig. 1, and a photograph of it in Fig. 2. The foil is

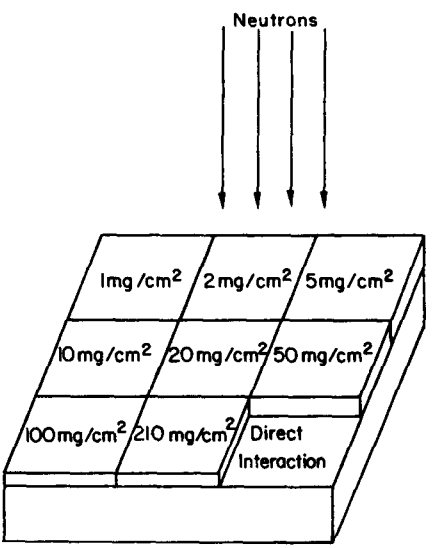

Fig. 1. Schematic diagram of the spectrometer-dosimeter,

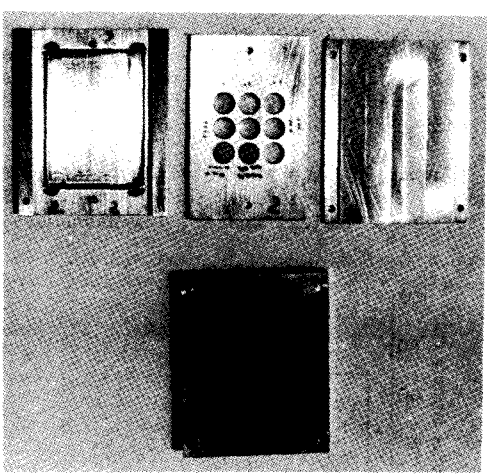

Fig. 2. Photograph of the spectrometer-dosimeter.

divided into nine areas, eight of which are masked by polyethylene radiators of thicknesses ranging from 1mg/cm^2 to 210mg/cm^2. The ninth area is not masked and is used to assess the number of damage sites resulting from the foil background and from direct neutron interactions with the CR-39. The CR-39 foil is embedded in a stainless steel box with a wall thickness of about 400mg/cm^2. This box absorbs high energy recoil protons due to elastic scattering of fast neutrons with moisture in the air or with the phantom material. Two MNSs were built, each having a different set of polyethylene thicknesses. Thus, the simultaneous use of 14 proton radiators makes it possible to extract the neutron spectrum with much more detail.

The lower limit for the extraction of neutron spectra is imposed by the low sensitivity of the CR-39 for detection of protons having energies lower than 300 keV. Added to this is the technical difficulty of mounting polyethylene layers of about 0.7mg/cm^2 thickness, which corresponds to the range of 0.5 MeV protons. The maximum thickness of polyethylene radiator through which protons can pass and reach the CR-39 detector with sufficient energy to cause damage sites, increases with neutron energy. The device is based on the fact that for lower neutron energies, $\sim$ 0.5 MeV, there is no difference in the number of protons emerging from the radiators of different thicknesses, but for higher neutron energies, $\sim$15 MeV, (where the range of the most energetic proton is about 200mg/cm^2), there is a difference of about two orders of magnitude between the number of protons emerging out of the thickest and the thinnest radiators.

The energy spectrum was found in 10 energy channels with 14 polyethylene radiators, by a least squares minimization procedure which involves the proton yields produced beyond all the radiators and the revealing efficiencies of proton tracks in the CR-39 material. The damage sites on the CR-39 foil are revealed by chemical pre-etching for 24 hours at 35^{o}C, followed by electrochemical etching for 3 hours at 25^{o}C. The etchant solution is 9N KOH and the voltage and frequency are 1000V (RMS) and 1900 Hz, respectively. Either one or both sides of the foil were etched. It was found that electrochemical etching of only one side greatly enhances the contrast, giving a higher proton detection efficiency.

The spectrometer was irradiated with 14.8 MeV monoenergetic neutrons, as well as ^{252}Cf and ^{239}Pu-Be neutron sources. The calculated yield of protons emitted from each radiator was adjusted to give the same experimental ratios obtained with 14.8 MeV neutrons. Experimental yields are better reproduced when assuming a zero revealing efficiency for protons above 10 MeV and a maximum dip angle of 55^{o}.

Figure 3 shows the obtained ^{252}Cf spectrum as compared to the photoneutron spectrum obtained from a 16 MeV M.E.L. medical linear electron accelerator (Oncology Dept., Sheba Medical Center, Tel-Hashomer). The expected shift towards lower

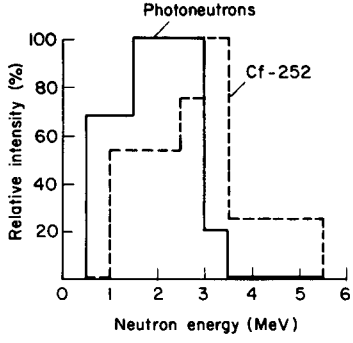

Fig. 3. ^{252}Cf and photoneutron spectra obtained with the miniature neutron spectrometer.

energies of the photoneutron spectrum is clearly seen (2).

When both sides of the CR-39 foil were etched it was observed that in the region not masked by polyethylene radiators the back side of the foil shows a larger yield than the front side. This is due to the fact that the CR-39 molecule contains hydrogen . (The thickness of the CR-39 foil used is equivalent to about 20mg/cm^2 polyethylene.) The back-to-front ratio of yields for ^{252}Cf and ^{239}Pu-Be sources is about 3.5, while for 14.8 MeV incident neutrons it decreases to about 1.5. This experimental fact might be used to obtain additional spectroscopic information.

Acknowledgement

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References

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