P-02

Neutron Beam Hardening with Heavy Water

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INTRODUCTION

Heavy Water Neutron Irradiation Facility of the Kyoto University Reactor (KUR) provides clinical neutron beam after alteration in 1996. The thermal neutron beam was cut with the filter (cadmium and boron) in order to improve the quality of neutron irradiation field for neutron capture therapy. Our interest is the investigation of the microdosimetric character of the new radiation field. It is important to understand the change of radiation quality for filtration. Microdosimetric single event spectra have been utilized for revealing the character of radiation field, and the absorbed dose in the tissue equivalent proportional counters (TEPC) has been calculated from the measured single event spectra. Microdosimetry is now a well established technique for the investigation of complex mixed radiation fields (1). In the present work, we measured microdosimetric spectra in order to gain the microdosimetric parameters of some epithermal neutron fields for boron neutron capture therapy at the KUR.

METHOD

Several kinds of neutron energy spectra ranging from nearly pure thermal to epithermal can be obtained by using both the spectrum shifters and the thermal neutron filters. In this study, we changed the thickness of heavy water from 0 to 90 cm on a mode of cadmium filtration.

A dosimetry technique using TEPC was applied for the direct measurement of the neutron absorbed dose from the differential components of the radiation field. The counter was a standard 0.5 inch diameter walled "Rossi counter". Measurements were performed at gas pressures of 28.2 and 56.3 torr, simulating 0.5 and 1 micrometer in unit density tissue, respectively. The counter preamplifier signal was fed from the irradiation area out to the control room where it served as input to Ortec 572 spectroscopy amplifier. Two or three gain spectra spanning the full dynamic range of event sizes were obtained with two or three runs, with adequate overlap for matching.

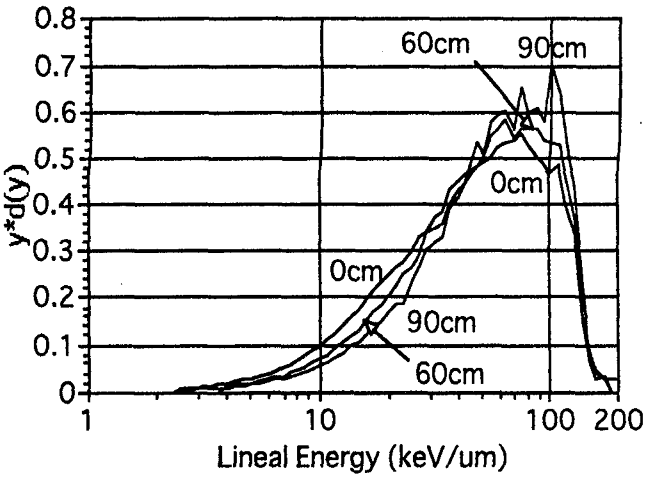

Fig. 1. Dose distribution of lineal energy yd(y) for 0, 60 and 90 cm in thickness of heavy water

Melding of different gain segments into a single logarithmically binned spectrum was performed after data acquisition, with the calibration factors obtained by collimated Cm source.

In order to get the absolute neutron dose, the following relation between absorbed dose D and the mean number of event per unit absorbed dose n was used (2).

$$n = D/(k\ y_F)$$

where y_F is the frequency mean lineal energy in keV/micrometer, and k is a constant given by $k=0.204/d^2$ for a sphere when the dose is measured in Gy and the diameter d is the actual physical counter diameter in micrometer.

RESULTS AND DISCUSSION

The dose distribution of lineal energy is given in Fig. 1. The ordinate is displayed as yd(y) in order to present that equal areas under different regions of the function yd(y) correspond to equal doses. As shown in Fig. 1, the spectrum gets much increase in a high-LET component as the thickness of heavy water increases.

Figure 2 shows the dose mean lineal energy y_D as a function of thickness of heavy water. Increase in dose mean lineal energy y_D as a function of thickness of heavy water was observed. This is a shift from 58.7 keV/micrometer for 0 cm to 67.4 keV/micrometer for 90 cm. Figure 3 shows the frequency mean lineal energy y_F as a function of thickness of heavy water. The frequency mean lineal energy increased from 31.8 keV/micrometer for 0 cm to 40.3 keV/micrometer for 90 cm. These changes indicate neutron beam hardening with heavy water. The neutron absorbed dose (Fig. 4)

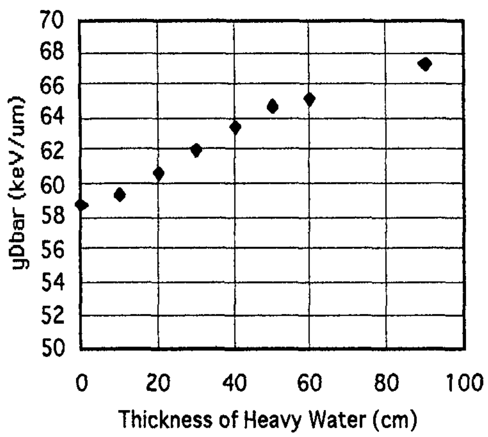

Fig. 2. Dose mean lineal energy y_D as a function of thickness of heavy water

was calculated by using the microdosimetric parameter y_F. Overall experimental uncertainty of the derived microdosimetric parameters has been estimated from the measured data to be frequency mean lineal energy y_F (10%) and dose mean lineal energy y_D (6%) (3). Therefore, the obtained neutron absorbed dose is likely to have 10% uncertainty. The neutron absorbed dose dose not decay exponentially as a function of thickness of heavy water. Dose rate on 90 cm thickness of heavy water decays to 1 % in comparison with one on 0 cm thickness. Results are good agreement with measurements with the activation method of gold foil.

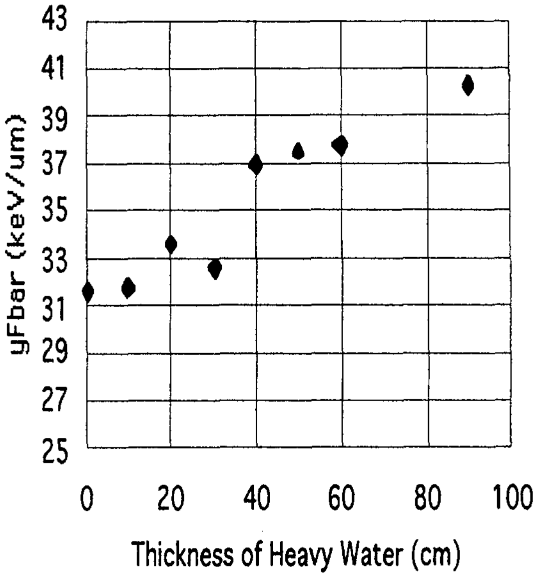

Fig. 3. Frequency mean lineal energy y_F as a function of thickness of heavy water

CONCLUSION

This research has as its objective to study the microdosimetry of an epithermal neutron field for boron neutron capture therapy at the Kyoto University Reactor. Microdosimetric measurements were done in order to gain the microdosimetric of some epithermal neutron fields for boron neutron capture therapy at the KUR. As a consequence, neutron beam hardening with heavy water was observed as a function of thickness of heavy water.

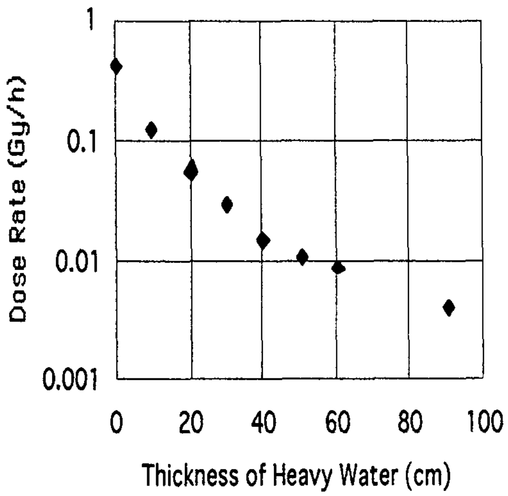

Fig. 4. Neutron absorbed dose as a function of thickness of heavy water

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