MEASUREMENT OF REACTION RATE DISTRIBUTIONS IN PHANTOM IRRADIATED BY INTERMEDIATE ENERGY NEUTRONS FOR EFFECTIVE DOSE EVALUATION

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ABSTRACT

Reaction rate distributions in a plastic phantom irradiated by 41- and 64-MeV quasi-monoenergetic neutrons were measured with a ^{238}U fission counter and solid state nuclear track detectors. Measured distributions were compared with those calculated by using the HERMES code system.

INTRODUCTION

From the view point of radiation protection in the radiation shielding design of high energy accelerators, it is important to establish an evaluation method of effective dose due to high and intermediate energy radiations. The HERMES code system (1) has been extended to calculate the effective dose (2). The accuracy of the code system, however, has not been evaluated for intermediate energy neutrons by experiments. Therefore, experiments were carried out for 41- and 64-MeV quasi-monoenergetic neutrons generated by the $^{7}Li(p,n)$ reactions with 43- and 68-MeV protons at an AVF cyclotron facility, TIARA (Takasaki Ion Accelerators for Advanced Radiation Application) facility, of Japan Atomic Energy Research Institute.

EXPERIMENTS

Figure 1 shows a cross sectional view of the experimental arrangement. Quasi-monoenergetic source neutrons ("41 MeV" and "64 MeV") of about 41- and 64-MeV were produced in 3.6 mm and 5.2 mm thick ^{7}Li-targets by 43- and 68-MeV protons, respectively. Source neutron spectra above 6- and 7-MeV were measured with a 5"ϕ x 5" BC501A liquid scintillation detector for the "41 MeV" and the "64 MeV". Absolute fluences of source neutrons in the monoenergetic peak were also measured with the recoil-proton counter telescope. Source neutrons emitted in the forward direction were introduced to an iron collimator of 11 cm diameter, while proton beam penetrating through the ^{7}Li-target was bent down by a clearing magnet to a Faraday cup. The phantom of 30 cm cube made of an acrylic resin was placed at the exit of the collimator. The intensity of source neutrons was monitored with a proton beam Faraday cup and two fission counters placed near the ^{7}Li-target, of which the efficiencies were calibrated by the recoil-proton counter telescope. Reaction rate distributions along the center line in the plastic phantom were measured with a ^{238}U fission counter (Centronic FC4A) and SSNTDs (Nagase Landauer Ltd. MR-3) which had been calibrated with a ^{252}Cf source.

EXPERIMENTAL RESULTS, ANALYSIS AND DISCUSSIONS

Energy spectra of transported neutrons were calculated with the HERMES code system. In the code system, neutron energy spectra above 19.6 MeV were calculated by the HETC-KFA2 code and those below 19.6 MeV were calculated by the MORSE-CG code with the DLC-119/HILO86 multi-group cross section library (3). Figure 2 shows the calculated energy spectra at the depths of 3 cm and 25 cm in the phantom for the "41 MeV". Error bars of the calculations in Fig. 2 show the fractional standard deviations. The relative energy spectra of source neutrons below 6- and 7-MeV were assumed to be the values at 6- and 7-MeV for the "41 MeV" and the "64 MeV", respectively. Reaction rate distribution of the ^{238}U fission counter was obtained from the neutron spectra and fission cross sections (4, 5). Calculated and measured distributions of the reaction rate of the fission counter are compared in Fig. 3. The calculated distributions are in good agreement with the experimental ones at the depth up to 15 cm in the phantom, while overestimates about 25% at the depth of 25 cm. The neutron energy spectra for whole regions were also calculated by the MORSE-CG code with the HILO86 library. The calculated distributions with these energy spectra are also in good agreement with the experimental ones even at the depth of 25 cm.

Reaction rate distributions of SSNTDs were also obtained from the neutron spectra and an energy response calculated by a newly-developed Monte Carlo code (Y. Nakane et al.) in which the energy range of incident neutrons had been expanded to intermediate energy. Calculated and measured distributions of reaction rates of SSNTDs are shown in Fig. 4. The calculated distributions for the "41 MeV" are in good agreement with the measured ones within 15% at the depth between 10 and 25 cm in the phantom, while those for the "64 MeV" are about 50% higher than the measured ones at the depth after 20 cm. These disagreements probably come from the energy response of SSNTDs for the incident energy of around 64 MeV. At the depth up to 5 cm, the calculated distributions for both the "41 MeV" and the "64 MeV" are lower than the measured ones. The contribution of the incident neutron spectra below 6- and 7- MeV to reaction rate distributions is estimated about 30% for the SSNTDs at the depth up to 5 cm. This discrepancy can be attributed to the assumption of source neutron spectra below 6- and 7-MeV. For the fission counter, that contribution is estimated to be in less than 4%.

SUMMARY

Reaction rate distributions of the fission counter and the SSNTDs in the plastic phantom using 41- and 64-MeV quasi-monoenergetic neutrons were measured and compared with those obtained from fission cross sections, an energy response and energy spectra calculated with the HERMES code system. Calculated distributions of the reaction rate of the fission counter obtained with the energy spectra by the MORSE-CG code and the HILO86 library are in good agreement with the experimental ones for the "41 MeV" and the "64 MeV". Calculated distributions of the reaction rate of the SSNTDs for the "41 MeV" are in good agreement with the measured ones within 15% at the depth between 10 and 25 cm in the phantom, while those for the "64 MeV" are about 50% higher than the measured ones at the depth after 20 cm.

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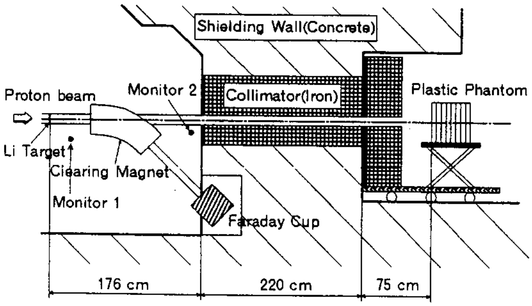

Figure 1. Cross sectional view of the quasi-monoenergetic neutron source facility.

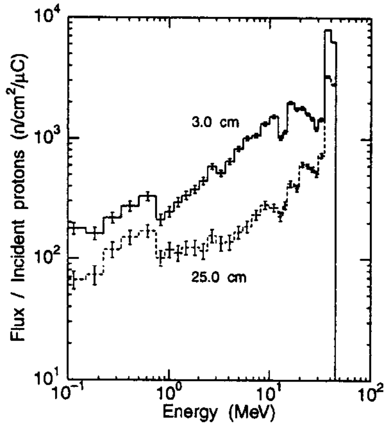

Figure 2. Calculated energy spectra of transported neutrons at the depths of 3 cm and 25 cm in the phantom for the 41 MeV quasi-monoenergetic neutrons.

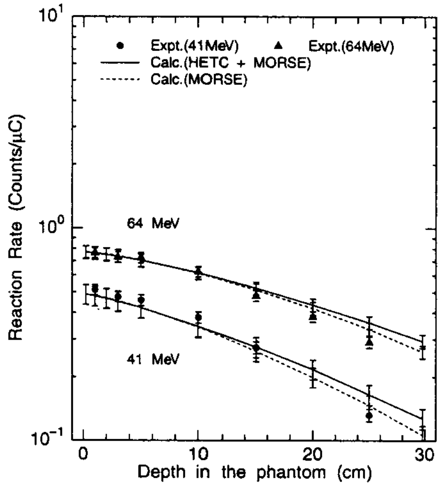

Figure 3. Calculated and measured distributions of the reaction rate of the ^{238}U fission counter.

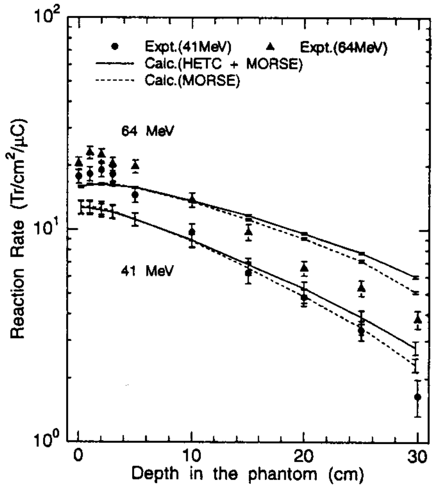

Figure 4. Calculated and measured distributions of the reaction rate of the SSNTDs.