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Measurement and Calculation of Dose Equivalent of Stray Neutrons outside of Shielding Wall of Proton Radio-therapy Room

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INTRODUCTION

It is desired to have a simple and convenient method to estimate dose equivalent (DE) of stray neutrons generated by proton beam of energy up to 250MeV usable for cancer therapy. The contribution of high-energy (above 20MeV) neutrons to the total DE of stray neutron in such cases is not so small. We have used to measure stray neutron dose a conventional Anderson-Braun (A-B) rem counter which is unapplicable to measure high-energy neutrons because of no good rem-response to these. In recent years, however modified A-B rem-counter has good response to also high energy neutron have been developed at a few high-energy physics laboratories[1-2].

Objects of this study are to get correction factor of conventional rem-counter on the basis of neutron dose equivalents measured by the modified rem-counter, and to propose a simple equation for stray neutron dose equivalent calculation on the shielding design of the proton radio-therapy facility.

METHOD

Two types of A-B rem-counters { H95-2 and 6060, modified counters made by IHEP, China and by HPI, USA, respectively, and a conventional counter(Studvic) made by ALNOR } were used in this experiment. DEs of stray neutrons originated in an iron target bombarded by 250 MeV proton beam around a proton beam irradiation room of PMRC were measured under the geometrical condition shown in Figure 1. Proton beam currents need to normalize DE value of stray neutrons was obtained from values of dose and dose-distribution of proton beam measured by an ionization chamber and by the imaging plate, respectively. An equation for calculating stray neutron dose fit for this experimental result was examined on the assumption proposed by Thomas that neutron energy spectra are in equilibrium state (1/E spectrum) after passing through shielding material thicker than several times of mean free path of neutrons which have kinetic energy higher than about 100 MeV when proton energy is higher than few hundred MeV[3].

DISCUSSION

From the results shown in Figure 2, ratio of DE measured by the modified counter to that by the conventional counter is slightly depend on polar angle (θ) with respect to proton beam direction and about 1.7 at 0 degree of the angle. An equation shown in Figure 3, which gives imaginary DE as a function of the polar angle (θ) at position 10m away from the target as neutron source was derived by the least mean square method from data plotted in Figure 3, given by the measured DE values and known neutron attenuation coefficients of shielding materials.

RESULT

We propose $DE(\theta, T_t) = 2*540EXP\{3.81(COS\theta -1)\}EXP(-\Sigma\mu_i T_i)$ as an equation by which dose equivalent of stray neutron outside of the shielding counting on safety factor 2 is given, where T_t is $\Sigma\mu_i T_i$, μ_i and T_i are attenuation coefficient and thickness of shielding material ' i', respectively.

Reference

(1) C. Borattari, et al ; NIM in Phys. Res. A 297, 250-257, 1990
(2) Li Jianping, et al ; Radiat. Protect. Dosimetry, 67, 179-185, 1996
(3) R. H. Thomas ; Engineering Compendium on Radiation Shielding III, 167, 1970

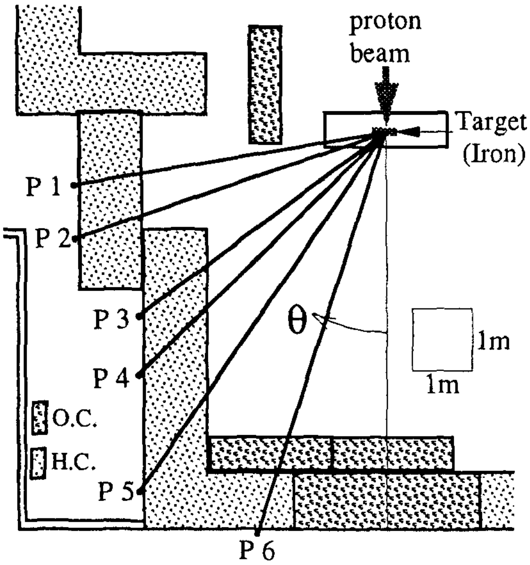

Fig. 1 Experimental arrangement to measure dose equivalent (DE) of stray neutrons from the iron target bombarded by 250MeV proton beam.

rem counter set position	target-counter distance	polar angle(θ)
P 1	5.10m	80.2°
P 2	5.35m	69.8°
P 3	5.12m	51.4°
P 4	5.80m	43.6°
P 5	7.36m	32.8°
P 6	7.23m	16.9°

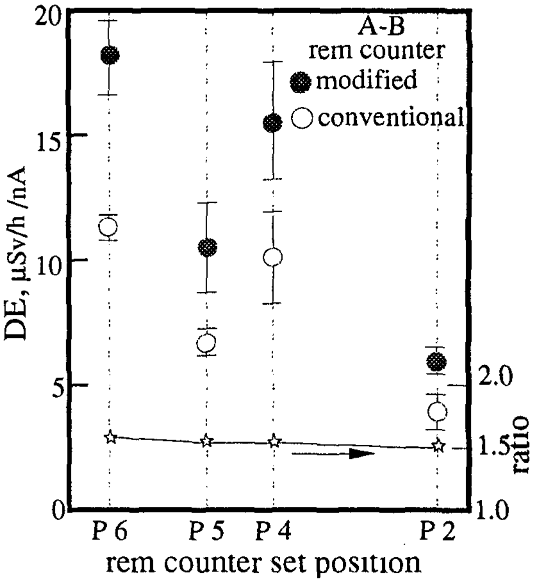

Fig. 2 Comparison of DEs of stray neutrons measured by modified A-B rem counter with those by conventional A-B rem counter .

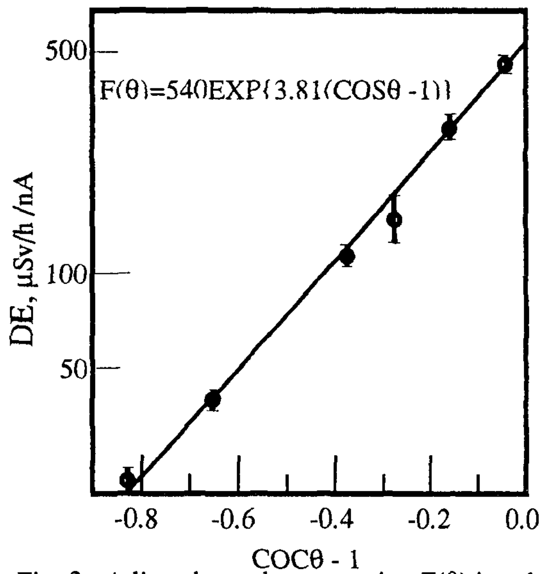

Fig. 3 A line shown by a equation F(θ) is a dose distribution as a function of polar angle(θ) at a position 10 m evenly away from the iron target, which value of DE on the vertical axis was derived from measured DE divided by attenuation rate of the neutrons passing through shielding materials.

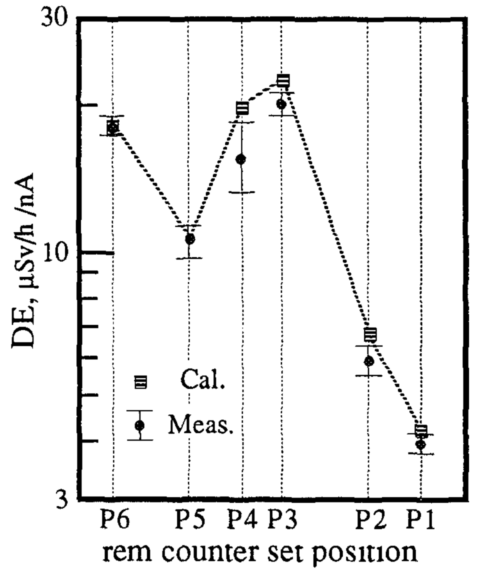

Fig. 4 DE values at rem counter set positions calculated by using an angular dose distribution equation F(θ) and the thickness of shielding materials together with measured DEs.