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001 Flux Distributions of 14-MeV Neutrons (II)

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The present paper reports the results of experimental study on the neutron flux distributions, which are measured by the positron activity of the $^{63}Cu(n, 2n)^{62}Cu$ reaction induced by 14-MeV neutrons from a Cockroft-Walton accelerator. The flux distributions are measured in the vicinity of the tritium target. Fairly good agreement is obtained between the two results of the relative flux distributions for a fresh and depleted targets. If the deuteron beam is used in wide spot, about 2cmϕ, the flux distributions have the same form, as for the different targets.

1. Introduction

Accelerator type 14-MeV neutron generators have been extensively used on many irradiation experiments. It is essential to know the fast neutron flux reaching sample boundaries in irradiation experiments with these generators. Nevertheless, the neutron flux distributions around the disk-shaped sources of neutron generators are considerably different from one installation to another, due to non-ideal behaviours of the experimental parameters. Among these non-ideal behaviours, the non-uniformity of tritium loading in the target appreciably affects the flux distributions, which have a tendency to become more asymmetric with a depleted target than using a fresh one. And neutron generators are usually operated in non-ideal conditions, and this makes the flux distributions different form.

Theoretical or experimental flux distributions of 14-MeV neutrons have been reported in several papers,[1)-3)] however these distributions do not always indicate actual distributions with our neutron generator, for the above reasons. The purpose of our experiments is to examine the flux distributions of 14-MeV neutrons in our irradiation facility.
These experiments are performed by counting the induced activities from copper foils, Previously, a depleted target was used to measure the flux distributions.[4)5)] The present paper reports the flux distributions of 14-MeV neutrons with a fresh target in its vicinity, and these two results are compared with each other.

2. Experimental procedure

2.1 Activation samples

Ninety sheets of circular copper plates (purity : 99.9% up, thickness : 0.5 mm, diameter : 10 mm, weight : 0.2367±0.0152 gr) are prepared as activation samples. Six sheets among these samples, are mounted as a set on a sample holder made of acryl plate (thickness : 2 mm) in the plane parallel to the target. The samples are placed in only one direction from the target center at intervals of 1.5 cm as shown in Fig. 1, due to symmetrical property of the flux distributions with respect to the target axis in the case of the deuteron beam in wide spot. Three sets of eighteen samples, mounted on three sample holders, are activated at the same time as a unit. Each of these sample holders is placed at different distance from the target plane. Sample-to-target distances are changed from 2.5 cm to 22.5 cm at intervals of 2.5 cm to measure the spatial distributions of 14-MeV neutron flux.

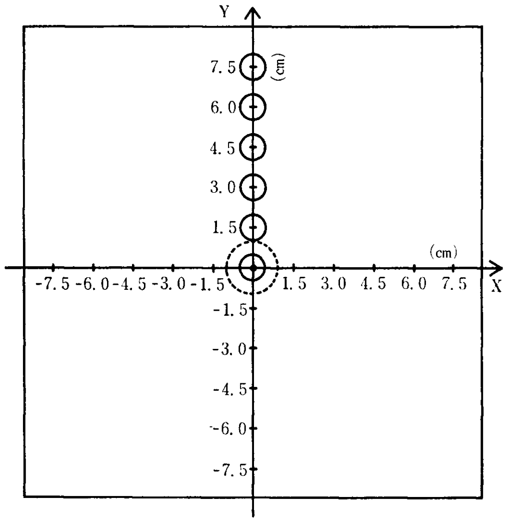

Fig. 1 Arrangement of activation samples, mounnted on acryl holder, for 14-MeV neutron flux distribution measurements Solid circle : sample size (1.0 cmϕ), dotted circle : effective target size (2.0 cmϕ), origin : target axis.

2.2 Irradiation

14-MeV neutrons are produced by the $^{3}H(d, n)^{4}He$ reaction with a Cockroft-Walton accelerator of Kinki University made by Texas Nuclear Corp., USA.
In order to maintain constant beam form and current, all controllable accelerator parameters are kept as constant as possible throughout the experiments. Operating conditions of the accelerator are adjusted as follows : extraction potential ; 5 kV, focus size of deuteron beam ; ca. 2 cm, accelerating voltage ; 120 kV beam current ; 400 μA, irradiation time ; 10 min.

Neutron intensity for different running number is normalized by measuring the monitoring activity from a copper foil that is placed at a distance of 2.5 cm from the target plane on its axis.

2.3 Measurements

The spatial distributions of 14-MeV neutron flux are obtained by counting the positron activity from the $^{63}Cu(n, 2n)^{62}Cu$ reaction (threshold energy : 11.8 MeV, cross section : 540 mb) induced by 14-MeV neutrons. During a cooling time of 3～35 minutes, the induced activity from each sample is measured one by one for a minute using a GM tube (NGMA 1210-1, Fuji Electric Co.), which is coupled to a counting system (SA-250, Fuji Electric Co.). The presence of ^{62}Cu (half life : 9.8 min) is confirmed from the decay curve calculated by the least squares method. The spatial distributions of 14-MeV neutrons from the fresh tritium target are obtained in relative value from counting rates of the individual samples, which are corrected for the differences of sample weight, cooling time and neutron intensity, and converted to relative specific activities. The measured countig rates without the corrections are 200～1500 cpm at a distance of 8 mm from the detector to the samples, during the cooling time.

3. Results and discussion

The flux distributions may show some differences from each other in the case of fresh and depleted targets, since the tritium loading in the target becomes more and more non-uniform approximately proportional to the operation time. The flux distributions for the depleted target have already been described in the reference 5). The present paper reports the results of measuring the flux distributions with the fresh target.

Fig. 2 shows the lateral flux distributions, which are parallel to the target plane, in relative value at distances of 2.5, 5.0, 7.5, 10.0, 12.5, 17.5 and 22.5cm from the target plane.

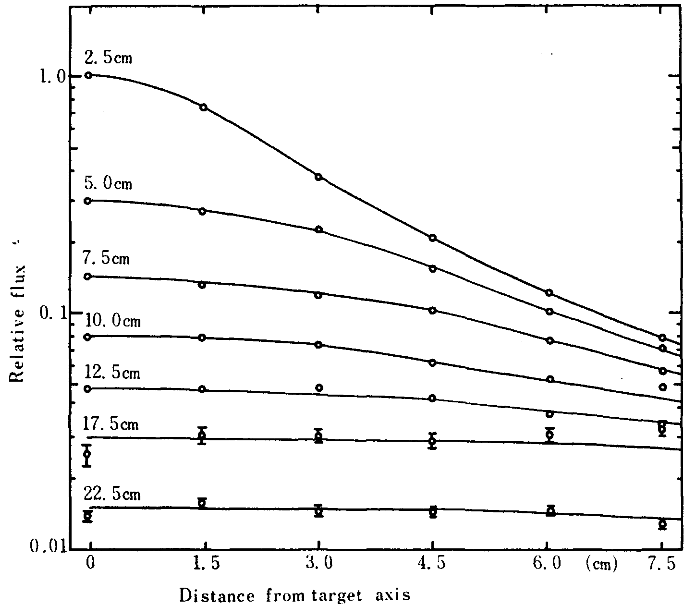

Fig. 2 Lateral flux distributions in relative value at distances of 2.5, 5.0, 7.5, 10.0, 12.5, 17.5 and 22.5cm from the target plane.

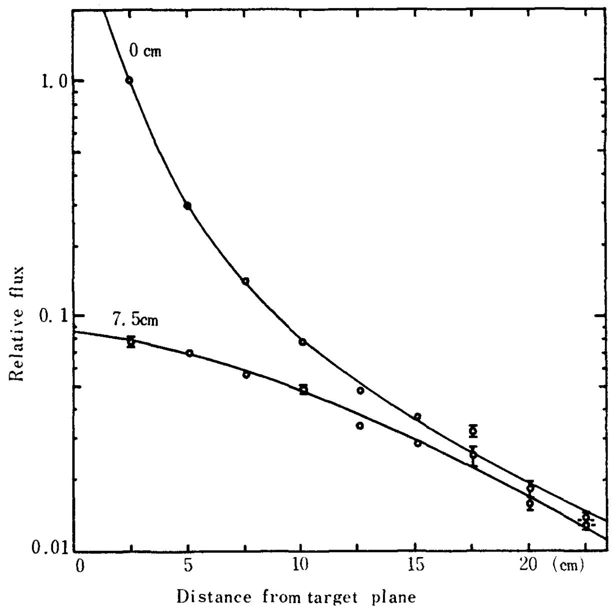

Fig. 3 Axial flux distributions in relative value along distances of 0 and 7.5cm from the target axis.

Fig. 3 shows the axial flux distributions, which are perpendicular to the target plane, in relative value along distances of 0 and 7.5cm from the target axis. The numerical values of the relative flux distributions are listed in Table 1. The obtained specific activities from the copper foils, which are proportional to the neutron flux, are normalized to unity at a distance of 2.5cm from the target plane on its axis. Statistical errors in standard deviations of the activation data are 1～10 percents.

Table 1 Spatial distributions of neutron flux in relative value

(A) cm / (B) cm	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
0	1.0000 ±0.0088	0.2962 ±0.0066	0.1412 ±0.0032	0.0787 ±0.0032	0.0480 ±0.0017	0.0366 ±0.0011	0.0253 ±0.0025	0.0183 ±0.0014	0.0137 ±0.0008
1.5	0.7373 ±0.0141	0.2687 ±0.0061	0.1323 ±0.0030	0.0798 ±0.0031	0.0481 ±0.0016	0.0337 ±0.0009	0.0307 ±0.0025	0.0206 ±0.0014	0.0158 ±0.0008
3.0	0.3797 ±0.0101	0.2264 ±0.0054	0.1197 ±0.0027	0.0742 ±0.0029	0.0489 ±0.0016	0.0328 ±0.0009	0.0307 ±0.0023	0.0218 ±0.0014	0.0147 ±0.0008
4.5	0.2100 ±0.0069	0.1552 ±0.0042	0.1029 ±0.0024	0.0626 ±0.0025	0.0444 ±0.0015	0.0310 ±0.0008	0.0291 ±0.0022	0.0179 ±0.0012	0.0147 ±0.0007
6.0	0.1226 ±0.0051	0.1019 ±0.0032	0.0764 ±0.0020	0.0527 ±0.0022	0.0377 ±0.0012	0.0297 ±0.0008	0.0308 ±0.0021	0.0174 ±0.0011	0.0146 ±0.0007
7.5	0.0789 ±0.0040	0.0713 ±0.0026	0.0569 ±0.0016	0.0490 ±0.0020	0.0339 ±0.0011	0.0281 ±0.0007	0.0323 ±0.0020	0.0158 ±0.0010	0.0128 ±0.0006

(A) : distance from target plane (B) : distance from target axis

Relative values are converted from counting rates of the individual samples, which are corrected for the differences of sample weight, cooling time and neutron intensity.

At first, the different flux distributions were estimated for the fresh and depleted targets, and wanted to get some correction figure to compare with each other. But on the contraly, fairly good agreement is obtained between the two results of the relative flux distributions. This result may express that the non-uniformity of tritium loading in the target is cancelled by using the deuteron beam in wide spot. The depleted target used in the previous experiment is that of about 50 hours operation, which is about the end of target life. Then, in the case of our accelerator, if the deuteron beam is used in wide spot, about 2cmϕ, the flux distributions have the same form, as for the fresh and depleted targets, and the reproduciable irradiation experiments can be expected. This may be used effectively in future in the irradiation experiments.

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