DEVELOPMENT OF NEUTRON MONITORING SYSTEM IN n - γ MIXED FIELD WITH A TWIN-TYPE $^{10}BF_3$ - $^{11}BF_3$ IONIZATION CHAMBER

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INTRODUCTION

A neutron monitoring system that could measure the contribution of neutrons separately from that of γ-rays in a n-γ mixed field has been developed in order to evaluate such a mixed field as encountered around a thermonuclear fusion reactor, a particle accelerator and a nuclear fission reactor. The characteristics of the detectors have been pre-checked with an Am-Be neutron source and then the experiments have been carried out around a target of the electron linear accelerator installed at the Radiation Laboratory in Osaka University and also in the D_2O facility of the research reactor in Kyoto University. In the former case the radiation field consists of burst X-rays and fast neutrons, which could simulate the field around a proposed fusion reactors such as Helical or Tokamak. On the other hand, in the latter case the field consists of stationary thermal neutrons and γ-rays, and it would be useful for the detector system to be tested in simulating the field of environmental level.

The main purpose of the present experiments is to establish a detecting system of a wide dynamic range that could measure all kinds of n-γ mixed fields, that is, various fluence rates and mixed ratios which could be realized just near the radiation generator and also far from it, namely the environmental level.

EXPERIMENTAL APPARATUS

In order to detect neutrons separately from γ-rays it is essential to explore such materials possessed with different sensitivities for neutrons and γ-rays. Namely, one is sensitive to both neutrons and γ-rays, and the other is only to γ-rays. The difference between the two output signals could correspond to that of neutrons. In case of a gas counter ^3He and ^4He gases are usually adopted. In the present experiments, however, a twin-type ionization chamber filled with $^{10}BF_3$ and $^{11}BF_3$ gases in each chamber has been prepared. The chamber is of a disk shape, diameter and thickness of which are 16 cm and 6 cm, respectively, and a rod-type electrode is inserted to each chamber. The applied voltage has been so adjusted as could be operated within the ionization chamber region. In the $^{10}BF_3$ chamber the thermal neutrons would react with ^{10}B and the emitted α-particle and ^7Li-particles would ionize the $^{10}BF_3$ gases. This chamber, however, also acts as a usual ionization chamber for γ-rays, and hence the output signal is attributed to both neutrons and γ-rays. On the other hand, as $^{11}BF_3$ chamber is insensitive to neutrons, the output would correspond only to γ-rays, that is, the exposure due to γ-rays could be measured without the influence of neutrons.

With this twin-type chamber the mixed field of high-fluence rate could be measured by the output current, while that of an environmental level by the counting method.

EXPERIMENTAL RESULTS AND DISCUSSIONS

In the beginning the experiments have been carried out with the Am-Be neutron source to obtain the fundamental characteristics of the twin-type chamber. In Fig. 1 are shown the output currents of both $^{10}BF_3$ and $^{11}BF_3$ chambers as a function of the distance from the source, where the dose equivalent rate due to γ-rays evaluated with an air-equivalent ionization chamber is also shown. It is found that both signals of $^{11}BF_3$ and ionization chamber are possessed with the same attenuation gradient, that is, they would satisfy the inverse square law of distance. The gradient of the output signal from $^{10}BF_3$ chamber which correspond to (n + γ) signals is a little larger than the other's. This is probably due to the scattered thermal neutrons coming from all directions around the chamber. As the difference of both signals could clearly be observed, the contribution due only to neutrons would be found out by taking subtraction between both signals.

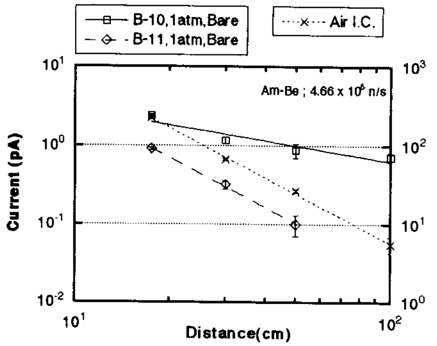
In Fig. 2 are shown the experimental results with this chamber set around the target of the electron linear accelerator. The energy, the peak current and the repetition rate of the electron beam are 28 MeV, 1 A and 60 pps, respectively, and the material of the target is Ta. The angular dependence of the output current from both chambers set at 3 m from the target is shown in the figure. The signals of both chambers increase towards the beam direction, which corresponds to the fact that the intensity of the Bremsstrahlung X-rays is extremely intense in the forward direction of scattering. However, the subtraction of both signals comes to be flat, that is, the neutrons generated in the Ta-target by the X-n reaction reveal no angular dependence.

In Fig. 3(a) and (b) are shown the experimental results obtained with those chambers set inside the D_2O thermalized neutron irradiation facility of the fission reactor. It is found that both output currents due to thermal neutrons and γ-rays increase linearly with the reactor power and there exists difference of about two orders of magnitude between both signals. The linearity of the exposure due to γ-rays for the reactor power has also been ascertained with an air-equivalent ionization chamber.

CONCLUSION

The twin-type $^{10}BF_3$-$^{11}BF_3$ ionization chamber has been operated in such various n-γ mixed fields as of Am-Be neutron source, as around a target of the electron linear accelerator and as inside the D_2O thermalized neutron irradiation facility of the research reactor. As a result it has been confirmed that both neutrons and γ-rays could be evaluated independently in the mixed field with satisfactory accuracy by taking subtraction of both output signals.

The present measuring system will be expected to be useful to evaluate the mixed field that would appear around various kinds of particle accelerators and also proposed large-scale devices for the thermonuclear fusion.



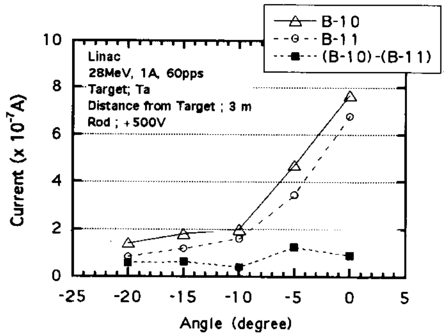
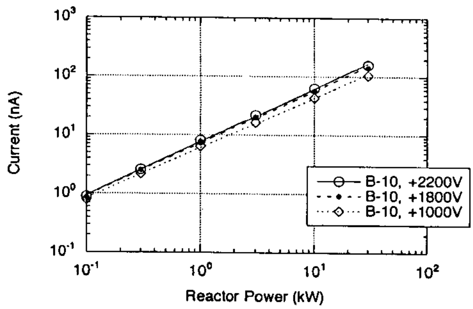
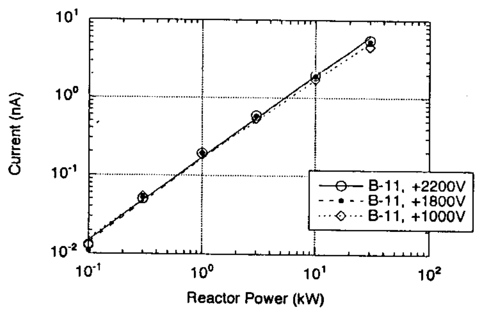


Fig. 1 Dependence of output currents of both $^{10}BF_3$ and $^{11}BF_3$ chambers on distance in the n- γ mixed field of Am-Be neutron source. The dose equivalent rate due to γ -rays measured with ionization chamber is also shown.

Fig. 2 Angular dependence of output currents of both $^{10}BF_3$ and $^{11}BF_3$ chambers operated around a target of an electron linear accelerator. The subtracted data correspond to the neutron component.



(a) $^{10}BF_3$ chamber



(b) $^{11}BF_3$ chamber

Fig. 3 Dependence of output currents of both $^{10}BF_3$ and $^{11}BF_3$ chambers operated inside the D_2O facility of the research reactor on reactor power.