DEVELOPMENT OF A DUAL TYPE IONIZATION CHAMBER SYSTEM FOR BURST n-X MIXED FIELDS

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INTRODUCTION

In the vicinity of high temperature plasma experiments for nuclear fusion studies, mixed radiation fields which are composed of X-rays and neutrons are expected to arise as burst-like pulses according to plasma shots. A typical operational condition is such that several-to-ten seconds plasma shots are given repeatedly in every ten minutes or so. It is therefore important from radiation protection point of view to have a monitoring sensor effective for real time and separate measurements of X and n components with a good dynamic range.

For that purpose we have designed and tested a dual type ionization chamber system to be used as area monitors around the coming Large Helical Device (LHD)(1) of NIFS. This might also be applicable to other case, for instance, radiation fields surrounding accelerator experiments. This system is composed of a pair of cylindrical vessels of the same size and shape, one containing ^{3}He gas sensitive to both n and X, and the other ^{4}He insensitive to neutrons. The ionization chambers have been examined with various kinds of radiation sources(2),(3). In the present study, we have carried out further irradiation experiments and discussed about the results.

CHAMBER SYSTEM

As the radiation dose sensor we have adopted the ionization chamber scheme to obtain the response in the current form, since it is required to cover a rather wide range of neutron fluence levels, sometimes accompanied by much stronger X-ray components, without suffering from the pile-up counting failure. In order to distinguish neutron contributions from X-rays, a dual-chamber system is proposed.

A dual type ionization chamber system is consisting of two cells of the same geometric shape, volume and wall material. The system turns the difference of reaction between isotopes to account. One of them is filled with pressurised ^{3}He gas, being sensitive to both neutrons and X-rays, and other filled with ^{4}He gas being sensitive only to X-rays. It will be possible to find out the neutron contribution by subtraction of the signal.

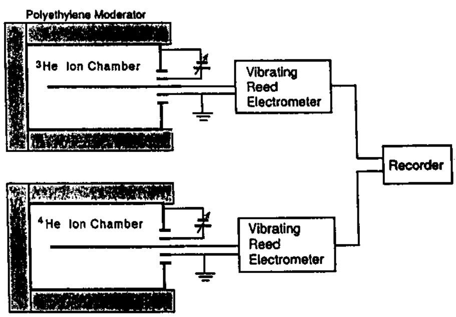

Figure 1. Chamber system.

Each chamber cell is a cylindrical vessel (80mmϕ x 200mm) of stainless steel (3mm thick) to give a gas volume of 1 liter. Measurable current range is 10^{-5}A $\sim 10^{-14}$A with a moderate time constant. Chamber cells with ^{3}He and ^{4}He gases of different pressure (1,2,3 atm) are prepared. Since we are interested in neutron energies up to a few MeV, a detachable polyethylene moderator (5 cm thick) is usually placed surrounding the chamber cells.

IRRADIATION EXPERIMENTS

(1) Responses to gamma rays ; The chamber characteristics irradiation against ^{60}Co gamma rays has been

carried out. The field intensity is varied by means of changing the source distance or source intensity. The response of ^3He and ^4He are quite similar to each other. Gas pressure dependence of the saturation current levels was given, there seems to hold good proportionality as expected. An apparent linear relation is attained to cover 8 orders of magnitude from 10^{-5} Gy/h to 10^3 Gy/h.

(2) Responses to thermal neutrons ; The neutron response of ^3He chamber has been surveyed by means of D_2O themarised neutron irradiation at the KUR fission reactor of Research Reactor Institute, Kyoto University. The chambers were placed about the center of the irradiation room, where is 1.5 m distant from Bi surface. The reactor power has been changed from 0.1 kW to 30 kW. The thermal neutron flux at this position is estimated by a different experiment as $0.96 \sim 1.88 \times 10^4$ n cm^{-2} s^{-1} at 1 kW operation, so that the observed ^3He current 0.35 nA should imply the sensitivity of the 1 atm ^3He chamber with moderator to be $0.019 \sim 0.036$ pA/(n cm^{-2} s^{-1}). Both output currents from ^3He and ^4He chamber are closely proportional to the reactor operating powers, or fission neutron yields, though the current ratio ^3He /^4He is high as $\sim 10^3$.

(3) Testing with mixed n-X fields ; Response to source distance characteristics have been examined by means of ^{252}Cf and ^{241}Am-Be whose neutron emission rate were 1.5, 3.6, 5.1×10^5 n/sec and 4.66×10^6 n/sec, respectively. The ^3He response reveal $r^{-1.8}$ or $r^{-1.7}$ decrease with distance r. This trend may be due to the increasing of thermalised neutron component or incidence of scattered neutron to the flank. For the 1 atm ^3He chamber with moderator, response currents against ^{252}Cf and ^{241}Am-Be are evaluated as 0.07 and 0.05 pA/(n cm^{-2} s^{-1}).

In addition, in order to estimate the effect of moderator, polyethylene blocks have been put on between ^{252}Cf source and ^3He ionization chamber. When 50 mm thick moderator was put on, the sensitivity of the chamber was recorded the highest value.

DISCUSSION

The ^4He response to several sources those are ^{60}Co, KUR(D_2O), ^{241}Am-Be are plotted in Fig.2, showing very good fitting to the line. This implies that the small amount of gamma rays coexisting with neutron can easily be separated with the dual-chamber.

Table 1 shows the sensitivity related with ^3He gas pressure and moderator. This response ratio means output current ratio to that of the 1 atm ^3He chamber with moderator.

Table 1. Sensitivity related with the ^3He gas pressure and moderator.

Neutron source	moderator	Response ratio 1 atm	Response ratio 3 atm
Thermal neutron	5 cm	1	1.87
	0 cm	6.26	13.1
^{252}Cf	5 cm	1	1.82
	0 cm	-	0.09
^{241}Am-Be	5 cm	1	1.82
	0 cm	0.04	0.11

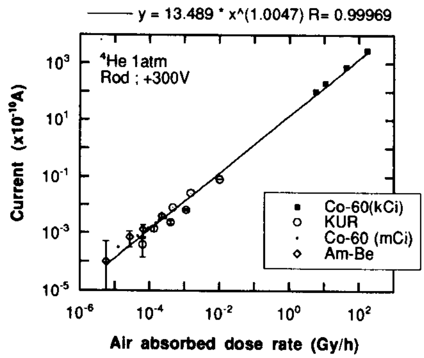

Figure 2. Responses to gamma rays, (1 atm ^4He chamber).

In order to compare the experimental result with estimation, ^3He reaction rate has been calculated by means of ANISN which is one dimensional discrete ordinates neutron transport code. The conditions of the calculation have been changed about type of neutron source, ^3He gas pressure, thickness of polyethylene moderator.

The 3 atm chamber generates 1.8 times current than the 1 atm one, as shown in Table 1. This result can not be explained by one dimensional calculation. This is related with mean free path of neutron in the chamber. The shape of the chamber is cylinder. From two dimensional view, the chamber is circle. The thickness of that is the same as the diameter at the center, and becomes thinner when recede the center point. When neutrons go into the 1 atm chamber from one direction uniformly, 48 % of neutron collides with ^{3}He, the remainder go through it. On the other hand, 96 % of neutron make reaction with ^{3}He in the case of the 3 atm one. These calculation can explain the results of the experiment.

When gas pressure in the chamber is made higher, the sensitivity for X(gamma)-rays is increased correspondingly, but that for neutron is not risen so much. Even if the gas pressure is 7 atm, the sensitivity is ascended only 1.02 times as large as that of 3 atm. Therefore, the gas pressure in the chamber is rather considered for the sensitivity of X-rays.

The neutron signals from ^{3}He are due to a thermal capture process which is high sensitive for thermal neutron and low for fast neutron. It is important to select a suitable thickness of moderator. A polyethylene moderator gives reducing energy, shielding and reflecting for neutron. As shown in Table 1, moderator performs only as neutron shielding in the thermal region. The same value has been given by the calculation of ANISN. On the other hand, for the fast neutron, moderator slows down neutrons to thermal neutron. The result of calculation indicates that the 5.5 cm thick moderator gives the highest sensitivity for a few MeV neutron. The ^{252}Cf irradiation test shows the same consequence as this.

Fig. 3 shows the response characteristic of ^{3}He chamber against neutron energy. By the effect of the moderator, the sensitivity of ^{3}He chamber becomes quite uniform for neutron energies up to a few MeV.

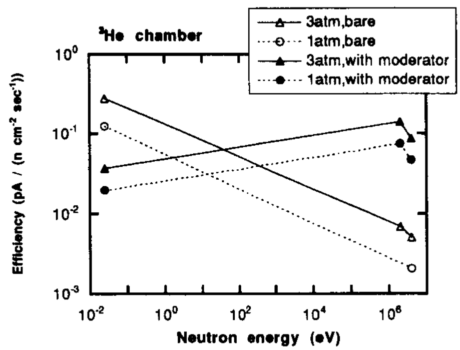

Figure 3. Response characteristic of ^{3}He chamber against neutron energy.

SUMMARY AND REMARKS

A dual type cylindrical ionization chamber system has been developed for dosimetry use of neutrons and X(gamma) rays. Several tests so far carried out in various field conditions seem to show good capability of the system.

Task and issues left for the future : (i) Tests in the burst-like pulse radiation fields (use of existing accelerators or plasma devices) using fast responsive electrometer (ii) n-X separation test in the field where n/X is small.

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