INTERCOMPARISON OF SOME PERSONNEL DOSIMETERS IN THE MIXED GAMMA AND NEUTRON FIELDS

Yoshihiro OGAWA, Yuichiro KIMURA, Yoshihide HONDA
Faculty of Science and Technology, Kinki University, Higashi-Osaka Japan
Kenichi OKAMOTO, Tadashi TSUJIMOTO and Kosuke KATSURAYAMA
Health Physics Division, Research Reactor Institute, Kyoto University, Osaka, Japan

INTRODUCTION

The personnel dosimeters such as film badges and thermoluminescence dosimeters (TLDs) are commonly used for radiation protection purposes as to penetrating radiation, gamma-rays and neutrons. However, gamma-ray and neutron doses obtained with these dosimeters are evaluated by each institute and/or dosimeter vendor using their original calibration factors and procedures. Therefore, personnel dosimetry intercomparison is very important not only for the improvement of dosimeter performances but also for the standardization of dose evaluation procedures. Much problems remain in neutron dosimetry rather than in gamma-ray dosimetry. Especially, neutron energy spectrum and mixed gamma-rays can affect neutron dose measurement and its evaluation procedure. In order to estimate the effects of these factors on measurements of neutron dose equivalent, an intercomparison of dose equivalent responses to thermal neutron for some kinds of personnel dosimeters was carried out under a variety of mixed field spectral conditions at Kyoto University Reactor (KUR) and Kinki University Reactor (UTR-KINKI). In this paper, some problems related to the precision and accuracy in the measurements of thermal neutron dose equivalent were investigated from the practical point of view.

EXPERIMENTAL

Five different mixed gamma and neutron fields at KUR and UTR-KINKI were used. These fields have different cadmium ratios and n/γ ratios, respectively. The specifications of the mixed fields are as folloes:

(1) mixed field I with dimensions of 300 x 300 x 300 cm at KUR heavy water facility,
(2) mixed field II with dimensions of 50 x 50 x 50 cm at KUR horizontal exposure tube No 2,
(3) mixed field III, the same as mixed field II, but different cadmium ratio and n/γ ratio from mixed field II,
(4) mixed field IV with dimensions of 20 x 20 x 10 cm, composed of bismuth scatterers and LiF tiles in the graphite reflector region at UTR-KINKI,
(5) mixed field V, the same as mixed field IV, but different cadmium ratio and n/γ ratio from mixed field IV.

The radiation characteristics of the mixed fields are shown in Table 1. The basic measurements made during this study were gamma-ray exposure rate, thermal neutron flux, cadmium ratio, n/γ ratio ($cm^{-2} \cdot mR^{-1}$) and n/γ ratio based on dose equivalent. Gamma-ray exposure rate was measured by TLD, and thermal neutron flux and cadmium ratio by gold foil activation method. The exposure dose is equal to the dose equivalent for gamma-ray, but the thermal neutron dose equivalent is assessed using a reference value of 936000 fluence per 1 mrem recommended by ICRP (1).

Table 1 Radiation characteristics of the mixed gamma and neutron fields at KUR and UTR-KINKI

mixed field	gamma-ray exposure rate (R/hr)	thermal neutron flux ($n/cm^2 \cdot sec$)	Cd ratio	n/γ ratio ($cm^{-2} \cdot mR^{-1}$)	n/γ ratio (based on dose equivalent)
I	$1.75 \times 10^{-2} \sim 3.40$	$3 \times 10^4 \sim 7 \times 10^6$	5000	6.91×10^6	7.41
II	6.22	2.59×10^6	491	1.50×10^6	1.60
III	6.35	3.88×10^5	252	2.20×10^5	0.235
IV	$4.11 \sim 4.70 \times 10^{-2}$	$2.57 \sim 3.13 \times 10^5$	5.9	2.37×10^7	25.3
V	$9.84 \sim 10.9 \times 10^{-2}$	$9.38 \sim 11.4 \times 10^4$	5.3	3.54×10^6	3.79

Dosimeters used for thermal neutron measurements are three film badges (hereafter denoted as dosimeter A, B, and C, respectively), and two TLDs (hereafter denoted as dosimeter D and E, respectively), commonly used in Japan. Each dosimeter was exposed in the every mixed fields under identical conditions. The evaluation of thermal neutron dose equivalent with each dosimeter was carried out by dosimeter vendors, respectively.

RESULTS AND DISCUSSION

As seen in Table 1, in these mixed fields cadmium ratio and n/γ ratio based on dose equivalent vary from 5000 (mixed field I) to 5.3 (mixed field V) and from 25.3 (mixed field IV) to 0.235 (mixed field III), respectively. Hence, we studied the effects of factors such as cadmium ratio and mixed gamma-ray dose on neutron dose equivalent measurement with each dosimeter.

Effect of cadmium ratio and n/γ ratio on thermal neutron dose equivalent measurement: when thermal neutron dose equivalent response (merm/fluence) of dosimeter was defined as a ratio of thermal neutron dose equivalent assessed with dosimeter to thermal neutron fluence measured by gold foil activation, its own trend in the response of dosimeter was obtained, although no systematic trend was found between film badges and TLDs.

Dosimeter A showed no definite trend in the responses with changes of cadmium ratio and n/γ ratio in the irradiation fields, and the responses vary from 1.83×10^{-6} (mixed field I and II) to 1.22×10^{-6} (mixed field III).

Dosimeter B showed no definite trend in the responses with changes of cadmium ratio and n/γ ratio in the irradiation fields, and the responses vary from 8.80×10^{-7} (mixed field II) to 5.04×10^{-7} (mixed field IV). It should be noted that in mixed field III, which is of the highest gamma-ray contamination, no significant neutron dose equivalent could be obtained with dosimeter B.

Dosimeter C showed no definite trend in the responses with changes of cadmium ratio and n/γ ratio in the irradiation fields, and the responses vary from 1.21×10^{-6} (mixed field I) to 9.74×10^{-7} (mixed field IV).

Dosimeter D showed that the response decreased from 2.10×10^{-6} (mixed field I) to 1.24×10^{-6} (mixed field III) as decrease in cadmium ratio and increase in gamma-ray contamination, although no results were obtained in the mixed field IV and V, because of no participation.

Dosimeter E showed no definite trend in the responses with changes of cadmium ratio and n/γ ratio in the irradiation fields, and the responses vary from 1.38 x 10^{-6} (mixed field I) to 1.08 x 10^{-6} (mixed field III).

From above mentioned results, it may be concluded that each personnel dosimeter used in the experiments have fairly good performances for radiation protection purposes. The thermal neutron dose equivalent responses of the dosimeters have no large dependency on cadmium ratio (5000∼5.3) and gamma-ray contamination (n/γ ratio 25.3∼0.235 based on dose equivalent) except for dosimeter D, and the changing ratio of the measured values by individual dosimeters were within 1.7 (see in Fig.1 and 2).

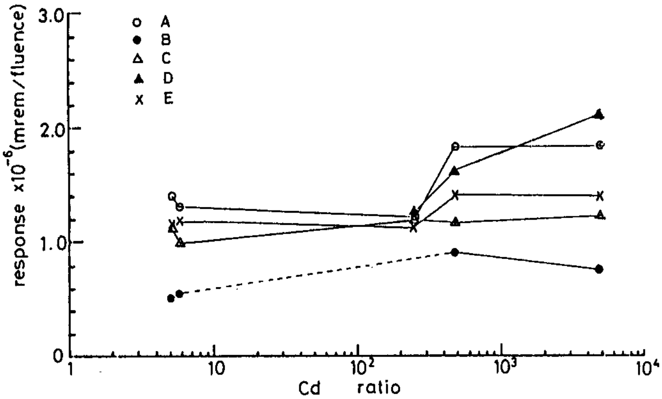

Fig.1 Comparison of thermal neutron dose equivalent response as a function of cadmium ratio

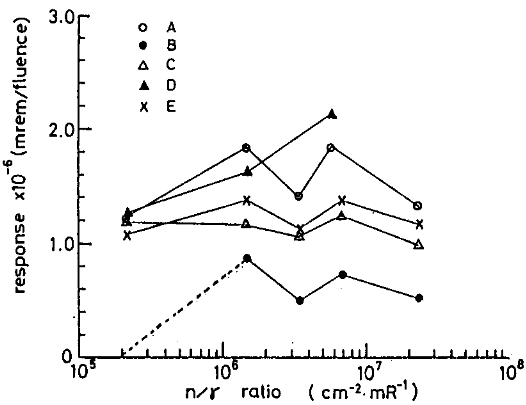

Fig.2 Comparison of thermal neutron dose equivalent response as a function of n/γ ratio

Table 2 shows a summary of the relative thermal neutron dose equivalent of individual personnel dosimeters normalized to ICRP recommended value as a reference value (1). The normalized thermal neutron dose provides a measure of accuracy of the measured value relative to the reference value. The percent standard deviations from the mean are measures of precision which describe agreement among individual measurements. As seen in Table 2, no consistent relationship between dosimeter asscracy or precision and incident cadmium ratio or gamma-ray contamination is indicated as reported by Sims et al. (2). The Nuclear Regulatory Commission (NRC) guidelines for personnel neutron dosimeters (3) suggest that dosimeters used in the dose equivalent range in mrem order should be accurate to within ± 50 % and that the standard deviation (a measure of precision) should be within ± 30 % of the mean. From the results shown in Table 2, dosimeter A, B (film badges) and dosimeter D (TLD) fail to meet the NRC accuracy guidelines in two of the five mixed fields. These results indicated that there is a difference of about 4 times in the measured values relative to the reference dose equivalent. However, all the dosimeters meet the precision of ±30 % standard deviation of the mean. The large difference of about 4 times in measured values relative to the reference value recommended by ICRP may be caused by different calibrations among the dosimeter vendors, since there is no large dependency on cadmium ratio and n/γ ratio in dose equivalent responses.

From the results obtained, it is suggested that the standardization of calibration of dosimeters is required from the practical point of radiation protection and safety.

Table 2 Comparison of relative thermal neutron dose equivalent and percent standard deviations of personnel dosimeters in various kinds of mixed gamma and neutron fields

personnel dosimeter	mixed field I	mixed field II	mixed field III	mixed field IV	mixed field V
A	1.71[1] (15.2)[2]	1.71 (10.5)	1.14 (17.5)	1.24 (15.3)	1.32 (15.2)
B	0.686 (19.7)	0.824 (10.3)	3)	0.487 (7.8)	0.472 (13.6)
C	1.13 (23.9)	1.08 (23.1)	1.11 (25.2)	0.912 (20.5)	0.983 (21.9)
D	1.97 (11.2)	1.50 (13.3)	1.16 (11.2)	4)	4)
E	1.29 (17.1)	1.28 (13.3)	1.01 (14.9)	1.10 (16.4)	1.06 (9.4)

1) relative thermal neutron dose equivalent
2) percent standard deviation
3) less than detectable limit
4) not participated

ACKNOWLEDGEMENT

A part of this study has been carried out under the Visiting Researcher's Program of Kyoto University Researsh Reactor Institute. The authers are indebted to dosimeter vendors for participation in this study.

REFERENCES

(1) ICRP Publication 21 (1971): Data for Protection against Ionizing Radiation from External Sources.
(2) C.S.Sims and R.E.Swaja (1982): Personnel Dosimetry Intercomparison at the Health Physics Research Reactor: a Summary (1974-80), Health Physics,42,3.
(3) Nuclear Regulatory Commission (1977): Personnel Neutron Dosimetry