A MODERATOR TYPE NEUTRON DOSEMETER BASED ON SILICON DIODES

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ABSTRACT : A moderator type neutron dosemeter is described and its response to realistic neutron fields from C.E.N. Cadarache-France is investigated, as well as its sensitivity to the gamma rays generated along with the realistic neutron fields.

Changes in response induced by the use of a moderator are observed throughout the experiments, with respect to the energy distribution of the neutron fluence and the dose equivalent. The Silicon detector sensitivity to the gamma ray component of these fields is also discussed.

Compared to an electronical neutron dosemeter without a moderator, for the same active area of the Silicon detector, the actual design shows a response 10 to 40 times higher to realistic neutron fields and a sensitivity to gamma rays up to 10 times lower.

INTRODUCTION

Previous work in the field[1,2,3,4] showed that the main problems in designing a neutron dosemeter based on Silicon diodes consist in finding the means to provide high gamma ray discrimination and to improve the response in the intermediate neutron energy range. A new approach to these problems is made using 2 Silicon detectors of 19.6 mm^2 active area surrounded by a small-size moderator.

While moderator type neutron equivalent monitors using passive detectors[5] require full moderation of neutrons over the whole neutron energy range (from thermal to 14 MeV), the use of Silicon detectors led to the concept of a "selected" energy range for moderation, which consist in moderating neutrons up to a certain energy and detecting higher energy neutrons directly as fast neutrons, using the same detector.

This is possible by using a polyethylene foil radiator deposed with a ^{10}B layer, positioned on the active surface of the Silicon diode. This radiator allows the detection of thermal neutrons through the $^{10}B(n,\alpha)^{7}Li$ reaction and fast neutrons detection through protons issued by fast neutron elastic scattering on Hydrogen atoms in polyethylene.

This "selected moderation" of neutrons requires moderators smaller in size than those used for "full moderation", allowing their use for personal dosimetry.

The use of a small size moderator has also the advantage of increasing the potential detection area of the dosemeter and allows a higher low amplitude threshold in order to discriminate pulses due to the gamma ray background.

THE MODERATOR TYPE NEUTRON DOSEMETER BASED ON SILICON DIODES

The detection assembly (moderator + diodes) shown in Fig.1 consists of 2 implanted Silicon diodes, having an active area of 19.6 mm^2, one of the diodes being provided with a polyethylene radiator deposed with 2 μm layer of B_2O_3 (96% ^{10}B enriched).

The pulses from the diodes are fed through two acquisition chains and then treated by a differential method.

Each diode is covered with an Aluminium shielding (0.3 mm thick), and both diodes are included in a hemispherical moderator provided with a cylindrical opening (Fig.1) intended to provide a direct detection for fast neutrons at normal and near normal incidence.

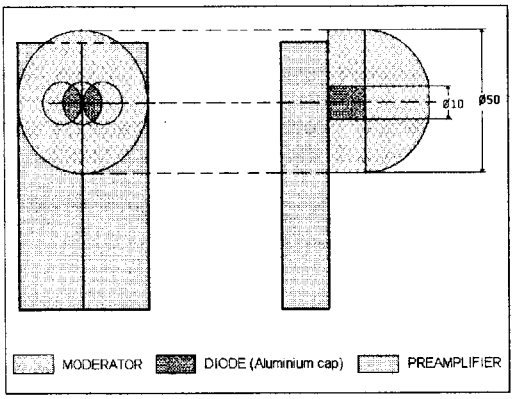

Fig.1. The detection assembly with moderator.

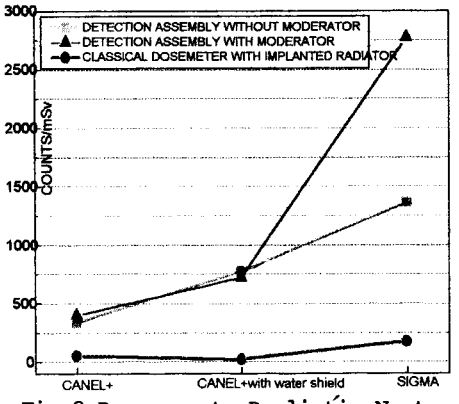

Fig.2 Response to Realistic Neutron Fields (Cadarache)

The low amplitude threshold of the system was at 100 keV and an informatic cutoff was imposed at 290 keV in order to discriminate gamma rays generated pulses up to a sensitivity of 10 counts/mSv for a ^{137}Cs gamma ray source.

THE IRRADIATION TESTS

Irradiation tests have been performed using the "Realistic Neutron Fields" from CEA/CEN Cadarache-France. The main parameters characterizing these fields are indicated in Table No.1, data being provided[6] by CEA/CEN - Cadarache and CEA/ IPSN/ DPHD Fontenay-aux-Roses. The following parameters are indicated: the spectral distribution of the neutron fluence Φ and neutron dose equivalent H for three neutron energy ranges : thermal (0.025 eV - 1 eV), intermediate (1 eV - 10 keV) and fast neutrons (10 keV- 14 MeV); the average neutron energy E(keV); and the effective energy E_H(keV), which is the dose equivalent average neutron energy.

Characteristics Neutron Field	Φ_{th} %	Φ_{Int} %	Φ_{fast} %	E keV	H_{th} %	H_{Int} %	H_{fast} %	E_{eff} keV
CANEL+	36	20	44	150	6	3	92	610
CANEL+ with water	43	26	31	80	10	7	83	68
SIGMA	97	1	2	72	46	4	50	1323

TABLE No.1.: Characteristic data for the Realistic Neutron Fields from Cadarache (France).

Irradiations of the detection assembly with and without moderator have been performed at normal incidence for each neutron field, with and without a PMMA phantom.

For each measurement, it was provided the value of the ambient dose equivalent $H^*(10)$ obtained from neutron fluence monitoring and the values of the corresponding fluence to dose conversion factors, as indicated by ICRP 60.

RESULTS

Dosemeter's response for the irradiation tests described above is shown in Fig. No.2, and is compared to the response of a differential detection system with two PIPS detectors, provided only with a radiator (and no moderator), developed at CEA/IPSN/DPHD/SDOS Fontenay-aux-Roses[2]. To enable comparison, the Silicon diodes active area has been normalized to 19.6 mm^2. In the diagram (Fig.No.2) the three type of fields (CANEL+, CANEL+ with water and SIGMA) were placed in an order reflecting their content of thermal neutrons. A statistics on the number of the pulses counted and an

investigation of their spectral distribution to observe the influence of the moderator to the dosemeter response, is shown in Fig.3 and Fig.4.

A part of this study is focused on the dosemeter response to the gamma rays generated along with the realistic neutron fields.

The response to gamma rays and the eventual direct neutron interactions with Silicon atoms in the diode were observed as the response on the diode without a radiator .

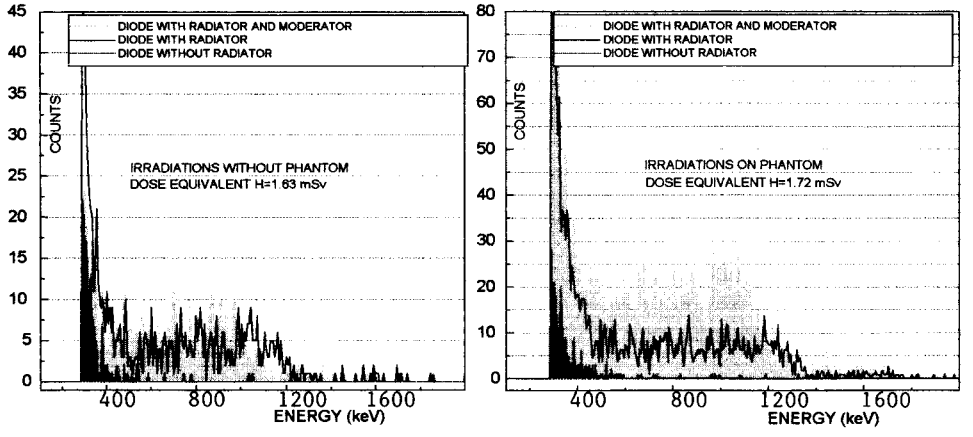

Fig.3 and Fig.4 : Cadarache irradiations on CANEL+with water shield. Pulse height spectra.

DISSCUTION AND CONCLUSIONS

For thermal neutrons and on phantom measurements it was obtained an over response when using the moderator, which is an expected result. A Cadmium shielding of a certain extent on the moderator's surface could overcome this inconvenient.

In the intermediate neutron energy range the sensitivity of the moderator system is higher than that obtained for the "classical system" using only the radiator. This is mainly due to the higher ^{10}B concentration in the radiator, but also to the presence of the moderator.

In conclusion, the moderator type neutron dosemeter investigated shows a high sensitivity for neutrons in the intermediate energy range where other detection systems using Silicon detectors proved to have a gap in response.

The small active area of the Silicon detectors, as well as the differential system used allows a very low gamma ray sensitivity of the detection system (10 counts/mSv), but it has also the disadvantage of providing a low sensitivity to fast neutrons.

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