§15. Development of an Improved Spherical Type Neutron Dose Monitor

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Moderator based neutron area monitors are used for a long time to detect neutrons with a wide range of energies from thermal to tens of MeV. These are designed to have a response that is as independent of neutron energy as possible, but given the difficulty of the problem that these are all deficient in terms of energy response to some extent. The common neutron monitors i.e. Roentgen equivalent mean (REM) counters, used for the routine surveillance, exhibit error for dose conversion, especially in the intermediate energy range.

An instrument for neutron dosimetry has been designed and constructed. It has the uniform response to wide energy of neutrons, and has the equal sensitivity to neutron comes from any directions. The monitor is spherical shaped, based on neutron moderation-absorption technique. It consists of four layers of spherical shells with 27.6 cm diameter and 12.6 Kg in weight. A Boron nitride (BN) shell for thermal neutron absorption was placed between Polymethyl Methacrylate (PMMA) and Polyethylene (PE). The two dimensional view of the monitor and arrangement of the TLD detectors inside it, is shown in Fig. 1.

Two types of TLD, $CaSO_4$(Tm)+^{6}LiF, named UD-136 can detect the thermal plus 1/v neutron and photon together and $CaSO_4$(Tm) named UD-110 can detect photon only, have been used for the measurement. Considering three dimensional arrangement, TLD detectors (12 sets) are placed between layers on 12 radiate axes at even interval corresponding to the apexes of regular polyhedron with 20 faces at two consecutive depths so that the monitor is equally sensitive in all directions, while one set of detector is placed at the center E of the monitor, as shown in Fig. 1. Although there are 8 axes in Fig. 1, the actual arrangement is three dimensional, having 12 axes. "A-a-E" is an example of a radiate axis. The total set of TLD detector was 25.

In order to demonstrate the performance of dose response of the monitor, comparing measured to expected dose, the instrument was irradiated in the reference field at Japan Atomic Energy Agency (JAEA), Facilities for Radiation Standardization (FRS), using standard ^{252}Cf bare source or D_2O moderated source to compare the experimental measured data. The neutron incident direction was considered as the median of an equilateral triangle, formed by three detectors of "A", which was towards as well as nearest the source, as shown in Fig.1. The standard irradiated doses of $H^*(10)$ were 1.48mSv and 1.25mSv for the D_2O moderated ^{252}Cf and bare sources, respectively. These values were forecasted from the result of test experiment, conducted at National Institute for Fusion Science (NIFS) using 0.11 MBq of bare ^{252}Cf source. The instrument was irradiated at a distance of 75cm from center of the source to the center of the instrument. The irradiation times were about 160 minutes and 48 hours of bare ^{252}Cf and D_2O moderated sources, respectively. Using Monte Carlo N-particle transport Code, MCNP5, the calculation has been also performed as the same geometry of the experiment. The reaction was considered ^{6}Li (n, α) ^{3}H for the calculation.

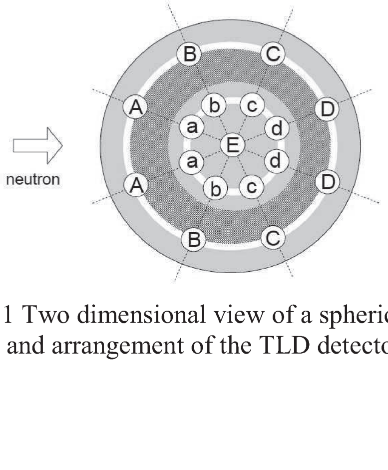

Fig. 1 Two dimensional view of a spherical monitor and arrangement of the TLD detectors

Neutron dose D was calculated using Eq.(1), where α_i is the linear co-factors of ith groups and R_i is the TLD readings of ith groups (i = A,a,B,b,C,c,D,d and E and N = 3, 5, 7 and 9 groups).

$$D = \sum_{i}^{N} \alpha_i R_i \qquad (1)$$

Considering different neutron energies and incident direction, 9 groups of TLD for different depths have been considered for the calculation. The MCNP calculated data and readout data were fitted using a regulation (linear) line, as shown in Fig. 2. From the regulation line, with in the uncertainties, almost a good agreement has to be found between the calculated values and the readout data of all groups TLD for ^{252}Cf (D_2O moderated) source. The neutron ambient dose equivalent, $H^*(10)$ was found suitable for 5 groups of TLD readings, which was derived using measured data, linear co-factors and standard irradiated dose of 1.48mSv from D_2O moderated ^{252}Cf source. The measured dose, $H^*(10)$ has found 1.43±0.56mSv for the bare ^{252}Cf source corresponding to expected dose of 1.25mSv. It can be concluded that within the considerable error neutron dose from low, intermediate and fast energies can be measured correctly by this monitor at radiation workplaces.

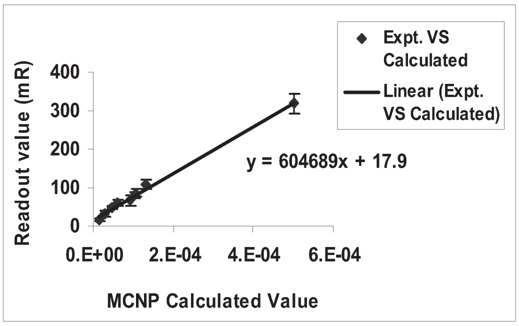

Fig.2 Measured VS MCNP Calculated values for 9 groups of detectors Cf-252 (D_2O moderated) source