The Nucleus, **44** (1-2) 2007 : 7-10

The Nucleus
A Quarterly Scientific Journal of
Pakistan Atomic Energy Commission
NCLEAM, ISSN 0029-5698

MODIFICATION OF THE NDOSEQ CODE IN THE LIGHT OF ICRP-60 RECOMMENDATIONS

A. ASHFAQ and *MATIULLAH

Pakistan Institute of Engineering and Applied Sciences (PIEAS), Nilore, Islamabad, Pakistan

(Received January 4, 2007 and accepted in revised form June 4, 2007)

After the availability of additional data, the International Commission on Radiological Protection (ICRP) revised the Quality Factors for neutrons and instead has recommended radiation weighting factors (WR) in their Report No. ICRP-60. These recommendations have serious consequences for many operational neutron dosimetry services. The ICRP-60 recommendations include the reduction in dose limits from 50 mSv to 20 mSv per year, change in the quality factors and the dose estimation in some circumstances down to a few mSv per year. The overall effect of the ICRP-60 recommendations is to reduce the detection threshold in order to account for the reduction in the effective equivalent dose. We have studied the impact of ICRP-60 recommendations on the response of CR-39 based fast neutron dosimeter and have modified the computer code NDOSEQ in the light of ICRP 60 recommendations. The NDOSEQ Code simulates the dose equivalent response of the electrochemically etched CR-39 detector to fast neutron in the energy range of 70 keV to 20 MeV for up to five hydrogenous front radiators.

Keywords: CR-39 polymeric nuclear track detectors, Neutron dosimetry, Flat dose equivalent response, ICRP-60 recommendations, Electrochemical etching, NDOSEQ code

1. Introduction

CR-39 polymeric nuclear track detectors dominate the field of neutron personal dosimetry, due to its relatively low cost, adequate sensitivity and high reliability. Therefore, CR-39 based personnel neutron dosimeters have been extensively reported [1-12] in the open literature and are in use in many countries in routine personnel neutron dosimetry. The neutron energy threshold of CR-39 is about 100 keV and being insensitive to photons, they are particularly suitable for use in mixed radiation fields [13].

The response of both chemically and electrochemically etched (ECE) bare CR-39 detector is known to be energy dependent [6, 14]. To overcome this problem, James et al., (1987) [15] developed a computer code NDOSEQ which yields nearly flat response over the energy range of 0.1 MeV to 19 MeV. They have also extended the use of above code for fast neutron spectroscopy [16-19]. Their optimized radiators-detector assembly is shown in Figure 1.

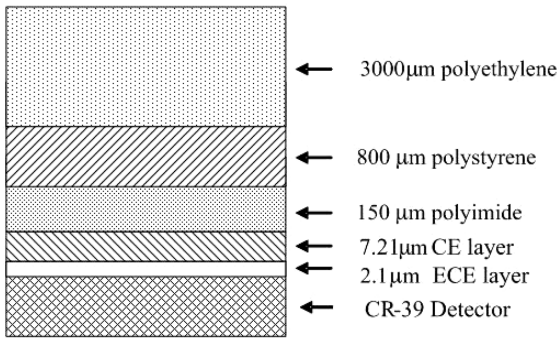

Figure 1. Radiators-detector assembly yielding nearly flat response.

The program NDOSEQ is capable of calculating the dose-equivalent response of a CR-39 fast-neutron dosimeter, used with or without front radiators, as a function of neutron energy, E_n and angle of incidence, θ. A numerical integration of the response over the forward hemisphere of neutron incidence angles may be performed by the program in order to evaluate the mean response of the dosimeter in both cylindrical and isotropic

* Corresponding author : matiullah@pieas.edu.pk

neutron fields. The program has the facility for inclusion of a nitrogen-containing first radiator (i.e. nearest to the CR-39 detector), which at energies upto ~ 10 MeV may slightly enhance the dosimeter response via the ^{14}N (n, α) reaction. The response of the NDOSEQ Code is based on neutron fluence to dose equivalent conversion factors recommended by the International Commission on Radiological Protection in their report No. ICRP-21 [20]. In order to meet the demand of ICRP-60, we have modified the NDOSEQ Code in the light of ICRP-60 [21] recommendations and have re-named as NDOSEQ-60.

2. Modification of the NDOSEQ Code

After successful operation of the computer code NDOSEQ [15], it was observed that its output response slightly depends on the number of layers of each radiators of the stack. Therefore, the code was repeatedly run and its output was studied as a function of the layers of each radiator of the stack. It was found that NDOSEQ gives relatively flatter response if each radiator of the stack is divided into 100 layers. Increasing the number of layers beyond 100 had no effect on the output response. Therefore, 100 layers were incorporated into NDOSEQ and it was then modified in the light of ICRP-60 recommendations i.e. neutron fluence to equivalent dose conversion factors were incorporated into NDOSEQ instead of 50 layers as reported by James et al. (1987) [15] and was re-named as NDOSEQ-60.

3. Description of the NDOSEQ-60 Code

The program NDOSEQ-60 is capable of calculating the dose-equivalent response of a CR-39 fast-neutron dosimeter, used with or without front radiators, as a function of neutron energy, E_n and angle of incidence, θ. A numerical integration of the response over the forward hemisphere of neutron incidence angles may be performed by the program in order to evaluate the mean response of the dosimeter in both cylindrical and isotropic neutron fields.

All of the required data is listed in an input file "NEQDOSE. Dat" and supplied to the program. Then program calculates the dose-equivalent response of the radiator-stack assembly as a function of the neutron energy, according to the values assigned to the control variables. The program has following six subroutines for different type of the calculations:

i. Subroutine STAKER

ii. Subroutine DETRNG

iii. Subroutine ALENG

iv. Subroutine FLREG

v. Subroutine BLREG

vi. Subroutine RMAX

For further details, the reader is referred to James et al. [15].

4. Results and Discussion

As mentioned earlier, a computer code which calculates the dose-equivalent response of electrochemically etched (ECE) CR-39 detectors to fast neutrons in the energy range 0.07-19 MeV was reported by James et al., (1987) [15].

After successful operation of the aforesaid code, the program NDOSEQ was modified and ICRP-60 neutron fluence to equivalent dose conversion factors were incorporated into it. The code was then re-named as NDOSEQ-60. The response of this dosimeter was determined as a function of neutron energy and angle of incidence. The accumulated response of the dosimeter for each neutron energy (E_n) and dip angle (θ) is calculated in program by summing the response due to each reaction occurring inside each of 100 discrete source layers within the CR-39 removed layers, within the un-etched bulk CR-39, and within each external radiator.

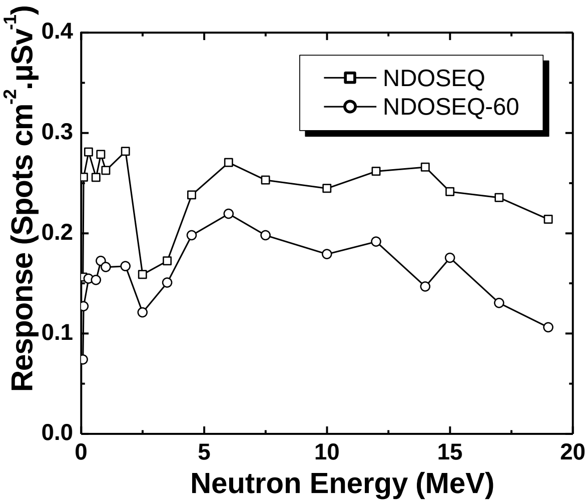

Figure 2. Comparison of the response of NDOSEQ and NDOSEQ-60 at normal incidence.

The mean of maximum and minimum response values, shown in Figure 2, may be defined as the ideal response of the dosimeter. According to this definition, the response of NDOSEQ is flat within 14.9% and the response of NDOSEQ-60 is flat within 14.6% in the energy range from 0.1 to 19 MeV. That is NDOSEQ-60 yields relatively flatter response than that of NDOSEQ.

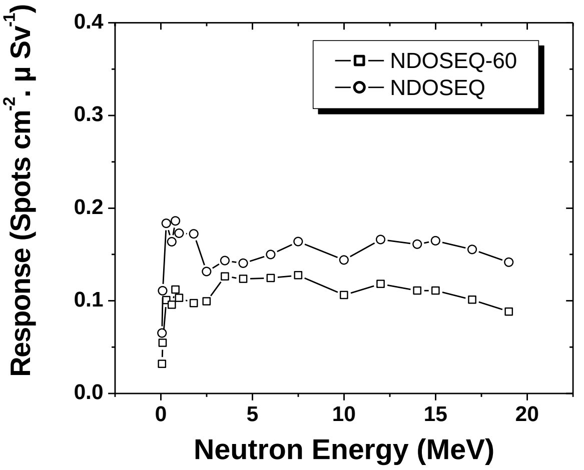

Figure 3. Predicted response of NDOSEQ-60 as a function of energy at neutron incident dip angle of 60º.

The response of the assembly is angle dependent. Therefore, response of NDOSEQ-60 was also studied at different neutron incidence angles and compared with the response of NDOSEQ in Figures 3 to 5 for the list angles of neutron incidence on the dosimeter. The response of the dosimeter is seen to fall approximately linearly with decreasing neutron incident dip angle. It may be seen in Figure 5 that there is a significant response for neutrons incident parallel to the detector surface (i.e. $\theta = 0°$).

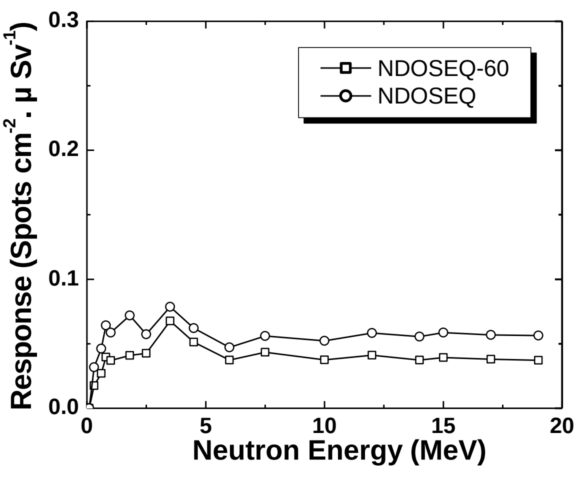

Figure 4. Predicted response of NDOSEQ-60 as a function of energy at neutron incident dip angle of 30º.

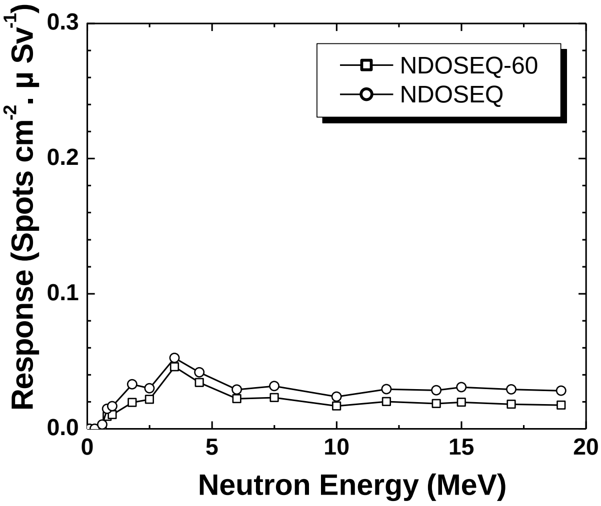

Figure 5. Predicted response of NDOSEQ-60 as a function of energy at neutron incident dip angle of 0º.

5. Conclusions

NDOSEQ Code has been modified in the light of ICRP-60 recommendations and has renamed as NDOSEQ-60. Like NDOSEQ, NDOSEQ-60 also yields nearly flat response in the energy range of 0.07 -19 MeV.

References

[1] Matiullah and S.A. Durrani, Radiat. Meas., **12** (1986) 657.

[2] S.A. Durrani and Matiullah, Radiat. Protect. Dosim., **23** (1987) 183.

[3] F. Fernandez, Radiat. Protect. Dosim., **66** (1996) 343.

[4] Matiullah, S.A. Durrani and G.A. Khan, Nucl. Instrum. and Methods, **B 34** (1988) 499.

[5] Matiullah and S.A. Durrani, Nucl. Tracks and Radiat. Meas., **15** (1988a) 511.

[6] Matiullah and S.A. Durrani. Nucl. Tracks and Radiat. Meas., **15** (1988b) 515.

[7] Matiullah, K. Kudo and K.M. Bukhari, Nucl. Tracks and Radiat. Meas., **19** (1991) 503.

[8] Matiullah, K. James and S. A. Durrani, Radiat. Protect. Dosim., **17** (1986) 149.

[9] Matiullah and K. Kudo Radiat. Protect. Dosim., **42** (1992) 313.

[10] Matiullah, N. Takeda and K. Kudo, Nucl. Instrum. and Methods, **B53** (1991) 223.

[11] T. Rashid, Matiullah, M. Gul, X. Yang and A. Bashir, Nucl. Tracks and Radiat. Meas., **22** (1993) 695.

[12] Matiullah and S. A. Durrani, Nucl. Instrum. & Methods, **B 27** (1987) 465.

[13] Matiullah and S.A. Durrani, Nucl. Instrum. and Methods, **B29** (1987) 508.

[14] S.A. Durrani and R.K. Bull, Solid State Nuclear Track Detection, (Oxford: Pergamon), UK.

[15] K. James, Matiullah and S.A. Durrani, Nucl. Tracks and Radiat. Meas.,**13** (1987) 3.

[16] Matiullah and S.A. Durrani, Radiat. Protect. Dosim., **20** (1987) 113.

[17] Matiullah, A.A., Aslam, K. James and S. A. Durrani, Nuclear Tracks and Radiat. Meas., **13** (1987) 131.

[18] A.A., Aslam, Matiullah and S.A. Durrani, Nucl. Tracks and Radiat. Meas., **15** (1988) 503.

[19] S.A. Durrani, Matiullah and A.A. Aslam, Nucl. Tracks and Radiat. Meas., **15** (1988) 499.

[20] Recommendations of the International Commission on Radiological Protection. ICRP-Publication 21(Ann. ICRP) (Oxford: Pergamon) (1979).

[21] Recommendations of the International Commission on Radiological Protection. ICRP Publication 60 (Ann. ICRP) (Oxford: Pergamon) (1990).