COMPARISON OF NEUTRON DOSE MEASURED BY ALBEDO TLD AND ETCHED TRACKS DETECTOR AT PNC PLUTONIUM FUEL FACILITIES

N.Tsujimura[1], T.Momose[1], K.Shinohara[1] and H.Ishiguro[1]

[1] Power Reactor and Nuclear Fuel Development Corporation, Tokai ,Ibakaki, Japan

INTRODUCTION

Power Reactor and Nuclear Fuel Development Corporation(PNC) has fabricated Plutonium and Uranium Mixed OXide(MOX) fuel for FBR MONJU at Tokai works. In this site, PNC/Panasonic albedo TLDs/1/ are used for personal neutron monitoring. And a part of workers wore Etched Tracks Detector (ETD) combined with TLD in order to check the accuracy of the neutron dose estimated by albedo TLD. In this paper, the neutron dose measured by TLD and ETD in the routine monitoring is compared at PNC plutonium fuel facilities.

DOSEMETER DESIGNS

Figure 1 shows a cross-sectional view of PNC/Panasonic albedo TLD. This dosemeter consists of eight TLD elements, four of them for beta/gamma ray and the other for neutron. Element 1 is $^{7}Li2^{11}B4O7(Cu)$ for compensation of gamma component, element 2 and 4 is $^{6}Li2^{10}B4O7(Cu)$ to mainly measure thermal neutrons of the external fields and albedo neutrons respectively. Neutron dose H is given by the next equation,

$$H=Kn \cdot Tn=Kn \cdot (T4-T1-C \cdot (T2-T3)) \qquad (1)$$

where T1,T2,T3 and T4 are thermoluminescence readings in unit R, calibrated to ^{137}Cs exposure, and Kn is the conversion factor from albedo neutron reading, Tn, to neutron dose. Energy and angular response of this dosemeter has been investigated by mono-energetic neutron fields/2/, moderated neutron fields, and also calculated by Monte-Carlo method. The conversion factor Kn is very energy dependent and appropriate value must be used to application areas. Default value of Kn for routine monitoring was determined experimentally by the comparison between TLD and neutron dose equivalent detector, "rem counter", in the typical workplace.

In this comparison study, we used Neutrak badge commercially available from Nagase- Landauer Ltd. as Etched Tracks Detector(ETD). This detector material is poly-allyl diglicol carbonate (trade name CR-39) and has a dimension size 10 x 5 x 1mm and high density polyethylene film(1mm) is attached in front of etched layer. Neutron dose is assessed by counted etch-pits N multiplied by conversion factor.

RADIATION FIELDS

The dominant nuclides which cause external exposure in the plutonium facility are ^{238}Pu,^{240}Pu and ^{241}Am. These emit gamma-ray(low energy X-ray), spontaneous fission neutrons and (alpha,n) reaction neutrons. Glove-box is shielded by polymethyl methacrylate(PMMA) and/or lead-contained PMMA, total thickness is about 50mm. Neutron energy spectra at various points in the workplace are measured by INS type multi-moderator ^{3}He detector/3/ and calculated by unfolding method. Average neutron energy in the typical workplace is about 1MeV, and the neutrons with energies above 100keV dominates approximately 90% of total neutron dose.

COMPARISON OF THE NEUTRON DOSE

Total 1,200 workers wore albedo TLD combined ETD at the fabrication process of MOX fuel from April, 1993 to March, 1994, and significant neutron dose were measured by TLD and/or ETD of 413 workers. Figure 2 shows the comparison between the albedo neutron reading Tn and counted etch-pits N. Superimposed lines present the maximum/minimum ratio obtained by the in-the-field experiments, in which albedo TLD and ETD are mounted on the water phantom installed in the typical workplace. The relation between N and Tn obtained by the combined dosemeter worn by workers agrees very well to that by experiments. Number of etch-pits is proportional to albedo reading and the average of N/Tn ratio is 0.3 with a standard deviation of 30% except the low dose range(below the detection limit, 0.2mSv). Figure 3 shows frequency of the quotients of the neutron dose measured by ETD and TLD, and the ratio are centered about 1.0 and almost within a margin of factor 2.

Though these dosemeters have a quite different energy response(TLD is sensitive to slow neutron, ETD fast neutron only), N/Tn ratio is constant. This results mean that the neutron has a uniform energy distribution in the typical workplace and TLD doesn't need any corrections, i.e. energy dependence at different workplace, for assessment of neutron dose.

CONVENTIONAL CALIBRATION METHOD

We have investigated the relation between N/Tn ratio and Kn at various neutron fields. Figure 4 shows the relation between the N/Tn and Kn. Though N/Tn ratio is observed in the range 0.3 to 10 over the average neutron energy range 0.5 to 5MeV, Kn is proportional to N/Tn with the next relation.

$$Kn = Ka \cdot 13.7 \cdot (N/Tn)^{0.92} \qquad (2)$$

where Ka is the angular dependence correction factor since these two dosemeter has a different angular response. Factor Ka varies from 1.0(perpendicular) to about 2.0, depending on incident angle, but the appropriate value of Ka is found to be fixed as 1.5 not to underestimate the neutron dose in the stray neutron fields encountered in ordinary work.

Therefore we propose the conventional calibration method for albedo TLD corresponding to the ratio of measured value by TLD and ETD. Using ETD as relative neutron monitor to study average N/Tn ratio in the typical workplaces, we can classify the types of neutron fields, where special Kn value is needed, and easily get appropriate Kn. As example, if the average neutron energy in the workplace is lowered by additional shielding around glove-boxes and N/Tn ratio changes remarkably, we may re-evaluate Kn value using equation (2).

CONCLUSION

The summary of this comparison study of TLD and ETD in the PNC plutonium fuel facilities are as follows.

(1) Neutron dose measured by albedo TLD has a good agreement with that by ETD.

(2) The ratio of N/Tn ratio obtained from two dosemeters worn by workers is almost constant in the workplace. Any location-dependent variations of N/Tn ratio are negligible except for special work conditions.

(3) The ratio of N/Tn ratio is an ideal index for Kn and we can easily get appropriate value of Kn using that ratio.

(4) Use of ETD as relative neutron monitor for personal monitoring, we can easily re-evaluate Kn.

REFERENCES

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3. T.Nakamura et al., Health Physics, 47, 5, 729-743, 1984

Type	Element No.	TLD and Filter
PNC/ Panasonic UD-809P	T1	(Front) $Cd/{}^{7}Li_2{}^{11}B_4O_7/Cd$ (Rear)
	T2	$Sn/{}^{6}Li_2{}^{10}B_4O_7/Cd$
	T3	$Cd/{}^{6}Li_2{}^{10}B_4O_7/Cd$
	T4	$Cd/{}^{6}Li_2{}^{10}B_4O_7/Sn$

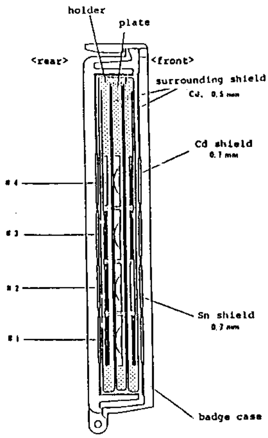

Fig.1 Cross-sectional view of PNC/Panasonic albedo TLD (type; UD-809P)

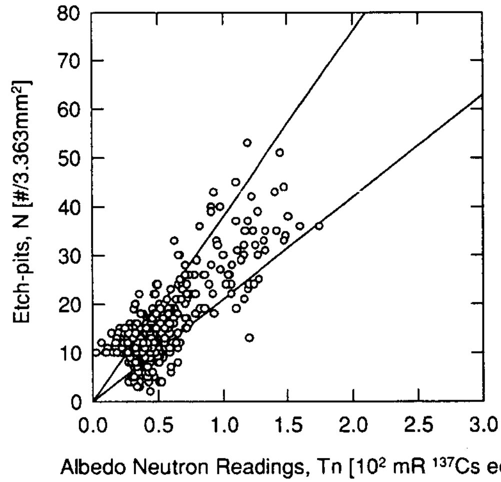

Fig.2 Comparison between the albedo neutron reading Tn and counted etch-pits N
(circle; worn by workers from April,1993 to March,1994
solid line; maximum/minimum ratio obtained by the in-the-field experiments)

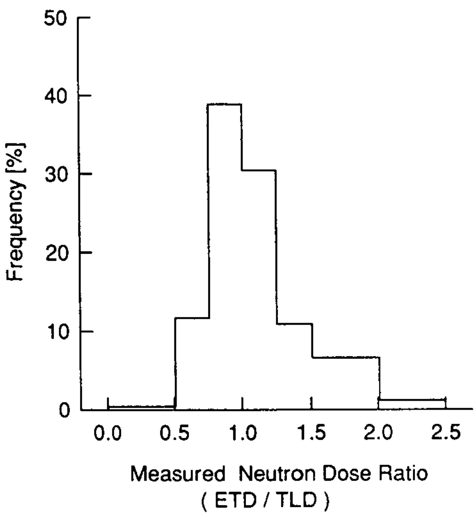

Fig.3 Frequency of the quotient of the neutron dose measured by ETD and TLD

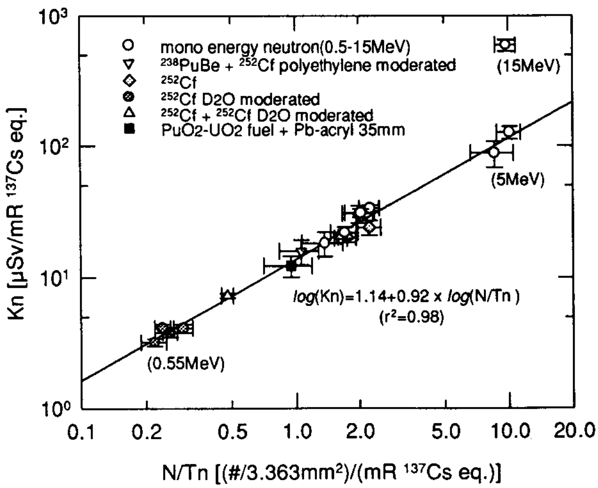

Fig.4 Relation between N/Tn ratio and Kn at various neutron fields