PERSONNEL DOSIMETRY SYSTEM BASED ON TLD AT PNC TOKAI WORKS

Hideharu Ishiguro, Seiji Fukuda

Health and Safety Division, Tokai Works, Power Reactor and Nuclear Fuel Development Corp, Tokai, Ibaraki-ken, Japan

INTRODUCTION

Power Reactor and Nuclear Fuel Development Corp. Tokai Works develops thermoluminescent dosimetry and applies it for routine personnel monitoring on a large scale in Japan. More than 3000 personnels per 3 months who work at nuclear fuel reprocessing plant, plutonium fuel fabrication plant and uranium enrichment facilities have been monitored with the PNC TLD badge and finger ring for past six years.

In order to measure the neutron dose which will be recieved by the personnel handling the plutonium of the order of kg at the plutonium facilities and also the β absorbed dose recieved by handling high radioactive materials at the reprocessing plant, we developed the PNC TLD badge for whole body exposure and two types of finger ring for partial exposure, which consists of some TL elements. It is now possible to evaluate gamma, beta and neutron doses on routine basis by using the PNC TLD badge.

PNC TLD BADGE AND FINGER RING DOSIMETER

The external view of the PNC TLD badge and two types of finger ring is shown in Fig. 1 and the composition of badge in Fig. 2. The external size is 46 × 76 × 11 mm and a material of the badge case is ABS plastic.

The TLD badge is composed of two TL elements ($CaSO_4$:Tm) for γ-ray, two thermal neutron sensitive TL elements (^6LiF + $CaSO_4$:Tm), one thermal neutron insensitive TL element (^7LiF + $CaSO_4$:Tm), six β-ray TL elements and one In foil.

All TL elements are products of Matsushita Electric Industrial Co. LTD.

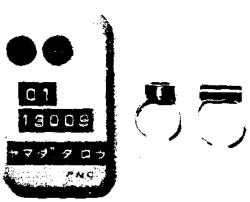

Fig.1 PNC TLD badge and finger rings

METHOD OF DOSE EVALUATION

γ-ray dose

γ-ray dosimeter (UD-200S) with energy compensation shield around the TL element ($CaSO_4$:Tm) composes the PNC TLD badge. Though the minimum detectable

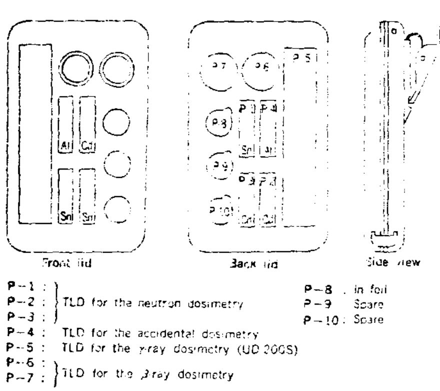

Fig. 2 Composition of PNC TLD badge

amount of this dosimeter is several mrem, 10 mrem per 3 months is employed as a recording level for the routine individual monitoring.

When γ dose is calculated, background dose of each dosimeter is automatically substructed by computer system.

This dosimeter has the good energy characteristics, the low fading effect, the high sensitivity and the ease of handling for the routine individual monitoring.

β-ray dose

The TL elements (UD-100M8) consists of thin Al film base of 30μm and thermoluminescence material ($CaSO_4$:Tm) in thickness of 60μm. Fig. 3 shows a composition of β-ray dosimeter and two sets of this dosimeter composes the PNC TLD badge.

The method of dose evaluation is the following.

Incident β and γ-rays are absorbed by TLD-1 and TLD-2 and in the TLD-3, only γ-ray is absorbed.

Consequently, the amount of thermoluminescence emitted from each TL element can be given, in case of the mixed β and γ radiation field, by the following equations;

$$L(1) = b_1(E)D_\beta + g_1(E)Dg + C \quad \cdots (1)$$

$$L(2) = b_2(E)D_\beta + g_2(E)Dg + C \quad \cdots (2)$$

$$L(3) = g_3(E)D_g + C \quad \cdots (3)$$

where

$L(i)$ = amount of luminescence emitted from TLD(i)
$bi(E)$= sensitivity of TLD(i) for β-ray with Emax(MeV)
$gi(E)$= sensitivity of TLD(i) for γ-ray with E(MeV)
D_β = β-ray dose
D_γ = γ-ray dose
C = amount of noise luminescence

Accordingly, obtaining bi(E) and gi(E) previously, the γ and β ray doses can be calculated by the following equations

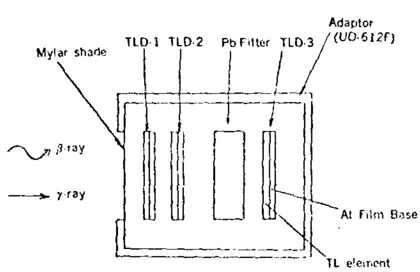

Fig.3 Composition of β-ray dosimeter

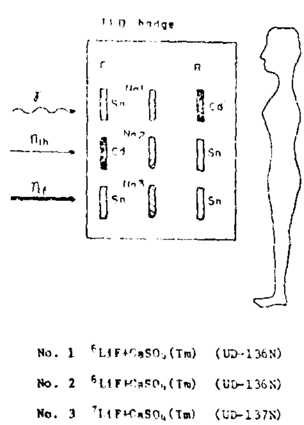

Fig.4 Composition of neutron dosimeter

$$D_{\gamma} = (L(3) - C)/g_3(E) \qquad \text{(mrem)} \ldots (4)$$

$$D_{\beta} = \frac{(L(1)-C)-[g_1(E)/g_3(E)](L(3)-C)}{b_1(E)} \qquad \text{(mrad)} \ldots (5)$$

Neutron dose

Neutron dosimeter incorporated in the PNC TLD badge consists of three TL elements and Cd Sn filters. Fig. 4 shows a composition of this dosimeter.

In the mixed radiation field of fast neutron, thermal neutron and γ-ray, the amount of thermoluminescent response of TL elements is interpreted by the following equations;

$$L(1) = n\sigma(E)\phi_{th} + G_1 \qquad \ldots (6)$$

$$L(2) = n\sigma(E)(\phi'_{th} + \phi'_{f}) + G_2 \qquad \ldots (7)$$

$$L(3) = G_3 \qquad \ldots (8)$$

where

$L(i)$ = amount of luminescence emitted from TLD(i)
n = proportionality constant
$\sigma(E)$ = the $^{6}Li(n,\alpha)^{3}H$ cross section
ϕ_{th} = the incident thermal neutron flux
ϕ'_{th} = the backscattered thermal neutron flux
ϕ'_{f} = the tissue moderated fast neutron flux, that is albedo-neutron flux
$G(i)$ = the luminescence caused by γ-ray to TLD(i)

If the effect of Cd and Sn filter to γ-ray is equal, G_1, G_2 and G_3 are equal, and so the thermal neutron dose (D_{th}) and the fast neutron dose(D_f) are calcurated by the following equations;

Table 1. The example of dose evaluation in the mixed exposure of β & γ rays

Source		dose					Maximum Energy of β-ray	Error* (β)
		Calculated			Measured			
β-ray	γ-ray	β(mrad)	γ(mrem)	β/γ	β(mrad)	γ(mrem)	(Mev)	(%)
^{90}Sr-^{90}Y	^{226}Ra	163	37	1.9	206	100	1.4	26
^{90}Sr-^{90}Y	Xray (220 keV)	344	32	10	1050	90	2.3	24
^{204}Tl	^{226}Ra	446	87	5.1	410	90	1.2	8
^{90}Sr-^{90}Y	-	354	0	-	320	0	2.5	10
^{204}Tl	-	61	0	-	50	20	1.0	18
^{147}Pm	-	1930	0	-	1930	9	0.22	0
-	^{60}Co	0	190	-	0	210	-	-
^{90}Sr-^{90}Y	^{60}Co	324	310	1.0	480	340	1.1	48
^{147}Pm	^{60}Co	1000	310	3.2	1140	360	0.21	14
^{90}Sr-^{90}Y	^{60}Co	51	62	0.8	80	60	1.4	18
^{90}Sr-^{90}Y	^{60}Co	165	62	2.7	200	60	2.5	21
^{204}Tl	^{60}Co	122	62	2.0	60	80	2.1	51

* Error $= \frac{\text{(Calculated}-\text{Measured)}}{\text{Calculated}} \times 100(\%)$

$$D_{th} = \frac{L(1) - L(3)}{k_1} = \frac{n\sigma(E)\phi th}{k_1} \quad \text{(rem)} \quad \ldots (9)$$

$$D_f = \frac{[L(2)-L(3)]-f[L(1)-L(3)]}{k_2} = \frac{n\sigma(E)\phi' f}{k_2} \quad \text{(rem)} \quad \ldots (10)$$

$$f = \frac{\phi' th}{\phi th} = \frac{L(2) - L(3)}{L(1) - L(3)} \quad \ldots (11)$$

Where, k_1 and k_2 are calibration constants to convert the luminescence into the dose equivalent, and f is the fraction effected by incident thermal neutron backscattered to the TLD(2), that is albedo-rate of thermal neutron.

Thus, it became possibleto evaluate separately fast neutron, thermal neutron and γ-ray doses in the mixed radiation field.

This neutron dosimeter was calibrated by PuO_2, C_f and AmBe neutron sources and paraffin phantom.

RESULTS

Exposing the β-ray dosimeter to the mixed field where β-ray and γ-ray doses are known by calculation, the dose evaluation was practically done with the method described above. The results are given in Table 1.

As seen from Table 1, the larger the β/γ ratio, the evaluation precision for β-ray dose improve more. In the routin monitoring, we think that minimum detectable amount of β-ray dose is about 100 mrad.

The sensitivity ratio (b_1/b_2) to β-ray between TLD-1 and TLD-2 in β-ray dosimeter is shown in Fig. 5, using the various β-ray sources. By this figure, we are able to obtain the information on β-ray maximum energy and radionuclide.

Table 2 shows comparison between personnel monitoring data and radiation dose rate by survey meter in plutonium facilities. The ratio is almost the same, showing that the neutron evaluation method is adequate. We think that minimum detectable amount of neutron dose is 10mrem for thermal neutron and 20mrem for fast neutron in the routine individual monitoring.

Table 2. Comparison between personnel monitoring data and radiation dose rate

Employee number or survey point	Personnel monitoring data by TLD badge		Radiation dose rate by survey meter	
	n Dose/γ Dose	n/γ	n(mrem/hr)/γ(mrem/hr)	n/γ
1	120 / 30	1.5	1.8 / 1.0	1.8
2	120 / 30	1.5	2.0 / 2.9	0.7
3	120 / 60	2.0	1.7 / 1.2	1.4
4	70 / 40	1.3	2.5 / 5.0	0.5
5	60 / 30	2.0	2.5 / 1.5	1.7
6	90 / 70	1.3	4.0 / 1.6	2.5
7	90 / 50	1.8	3.0 / 3.0	1.0
8	80 / 40	2.0	4.5 / 2.0	2.3
9	40 / 30	1.3	4.0 / 2.0	2.0
10	70 / 40	1.8	3.5 / 1.6	2.2
Ave.		1.7		1.6

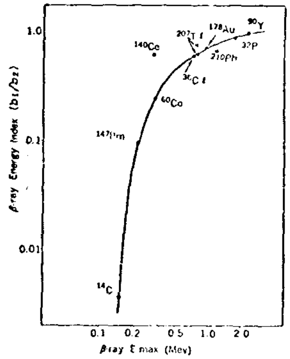

Fig. 5 Relationship between b_1/b_2 & $E_\beta max$