MEASUREMENT OF TLD ALBEDO RESPONSE ON VARIOUS CALIBRATION PHANTOMS

T. Momose,[1] N.Tsujimura,[1] K. Shinohara,[1]
H. Ishiguro,[1] and T. Nakamura[2]

[1]Power Reactor and Nuclear Fuel Development Corporation, Tokai, Ibaraki, Japan
[2]Cyclotron and Radioisotope Center, Tohoku University, Sendai, Japan

INTRODUCTION

The International Commission on Radiation Units and Measurements (ICRU) has recommended that individual dosemeter should be calibrated on a suitable phantom and has pointed out that the calibration factor of a neutron dosemeter is strongly influenced by the the exact size and shape of the body and the phantom to which the dosemeter is attached. As the principle of an albedo type thermoluminescent personal dosemeter (albedo TLD) is essentially based on a detection of scattered and moderated neutron from a human body, the sensitivity of albedo TLD is strongly influenced by the incident neutron energy and the calibration phantom.(1) Therefore for albedo type thermoluminescent personal dosemeter (albedo TLD), the information of neutron albedo response on the calibration phantom is important for appropriate dose estimation. In order to investigate the effect of phantom type on the reading of the albedo TLD, measurement of the TLD energy response and angular response on some typical calibration phantoms was performed using Dynamitron accelerator and ^{252}Cf neutron source.

DOSEMETER

Table 1 shows the constitution of PNC/Panasonic TLD badge used in this experiment. This TLD badge was designed to detect thermal neutron and fast neutron by using 4 TLD elements and cadmium and tin filters.(2) Element 1 has the sensitivity only to photon and used for photon compensation. Element 2 has major sensitivity to thermal neutron from working field. Element 3 has sensitivity only to epithermal neutron. Element 4 has major sensitivity to albedo neutron which was refracted from human body. The calculation of fast neutron dose equivalent is performed by following equation.(3-4)

$$H = Kn(T4-T1-C(T2-T3))$$

where H is the dose equivalent of fast neutron, Kn is the conversion factor, C is the correction factor for thermal neutron compensation, T1,T2,T3 and T4 are measured values of each TLD element.

Since, the value of Kn is based on T4 sensitivity, it is influenced by phantom characteristics such as material and shape.

EXPERIMENTAL METHODS

The fast neutron experiment was performed by using the Dynamitron accelerator at Tohoku university which produces monoenergetic neutrons of around 210 keV and 560 keV by the Li(p,n) reaction, around 1.1 MeV by the T(p,n) reaction, 5.0 MeV by the D(d,n) reaction, and 14.9 MeV by the T(d,n) reaction. The neutron energy was determined by using time of fright technique. The TLD on the phantom was placed in the forward direction to the axis of the projectile beam. The direct neutron flux incident on the TLD was measured with the ^{235}U fission chamber placed on in front of the TLD. Since the ^{235}U fission chamber is sensitive to low energy neutrons scattered from the surrounding objects, a hydrogen proportional counter which was sensitive only to fast neutrons was also placed at 45 degree to the beam axis as subsidiary monitor of the neutron flux. The experiment on angular response was performed by using the ^{252}Cf source at the PNC calibration facility.

The calibration phantoms used in this experiment were as follows. (a) paraffin phantom, (b) polymethyl methacrylate(PMMA) slab phantom (specified by Japanese Industrial Standard for calibration phantom of gamma ray personal dosemeter; JIS phantom), (c) cylindrical water phantoms. (we used two types, one was full water phantom and the other was cavity water phantom). These were chosen by the point of view of typicality and availability. (d) special anthropomorphic phantom which was made of neutron tissue equivalent material(5-6) and of which the physique was same as normal Japanese man of age from 30 to 35.(7) We considered that the anthropomorphic phantom was equivalent to living human body for neutron scatter. Table 2 shows phantom specification which were used in this experiment.

RESULTS AND DISCUSSION

Figure 1 (a) and (b) show the TLD energy response on various calibration phantoms. The element 4(T4) had higher sensitivity to fast neutron than a element 2 (T2) and a element 3 (T3) because of the absorption of albedo neutron by Cd filters beside T2 and T3. Sensitivitys of T2 and T3 are same to fast neutron. On the paraffin phantom, the sensitivity of element 4 which has high sensitivity to albedo neutron is same as the anthropomorphic phantom below about 1MeV, but in the energy range over 1MeV, the sensitivity on the paraffin phantom becomes about 1.5 times higher than anthropomorphic phantom. On JIS phantom, TLD response was higher than anthropomorphic phantom at the all irradiated energy region.

Figure 1 (b) shows comparison of anthropomorphic phantom and water phantoms. The response on the water phantom is in good agreement with the response on the anthropomorphic phantom, but cavity water phantom become lower than anthropomorphic phantom by a factor of 0.8. These experimental results suggest that water phantom is suitable for calibration phantom because of a good agreement with the anthropomorphic phantom which is considered as equivalent to human body.

The reason of the difference of energy response between the paraffin phantom and the anthropomorphic phantom seems to be the effect of the lung in the anthropomorphic phantom. The anthropomorphic phantom which have imitated lung with low density material has different scattering and moderating effects from the paraffin phantom which has uniform density.

The reason of the difference between the acrylate phantom and the anthropomorphic phantom seems to be the difference of the mean density. The density of 1.19 g/cm^3 of acrylate phantom seems to be too high as tissue equivalent.

The observed difference of energy response on cavity water phantom and anthropomorphic phantom seems to be because of the difference of lung volume. The cavity water phantom have large cavity of about 8 liters volume for lung which is two times as large as that of anthropomorphic phantom. Therefore incident fast neutron cannot be scattered and moderated well because of large volume of cavity in former phantom.

Figure 2 shows the angular response on various phantoms by using ^{252}Cf source. The distance between source and phantom surface was set at 75 cm and incident angle were changed from 0 degree to 180 degree. As the result of angular response of TLD element 4, the cavity water phantom is in good agreement with the anthropomorphic phantom. The water phantom has the good agreement at the front side incidence (from 0 to 90 degree) with the anthropomorphic phantom, but at the back side incidence(from 120 to 180 degree) it had a different response and the maximum difference ratio was about +400% at the 180 degree.

The acrylate phantom has also different response from the anthropomorphic phantom at almost all conditions and the maximum difference ratio was about -60%.

CONCLUSION

The energy response of the TLD on the 46x30x20cm elliptical cylinder phantom filled with water was in good agreement with the response on the anthropomorphic phantom. The TLD response on the 40x40x15cm PMMA slab phantom became higher than the anthropomorphic phantom at the all irradiated energy region. The TLD response on the 46x30x20cm elliptical cylinder paraffin phantom was in good agreement with the anthropomorphic phantom below about 1MeV, but in the range over 1MeV, the TLD response on the paraffin phantom became about 1.5 times higher than the anthropomorphic phantom. The angular response of TLD on the cavity water phantom considered as lung geometry was in good agreement with the anthropomorphic phantom. The phantom filled with water had different response from the anthropomorphic phantom with the maximum difference ratio of +400% at the back side incidence. The PMMA phantom had also different response from the anthropomorphic phantom at all incident angles and the maximum difference ratio was about -60%.

These experimental results suggest that water phantom (filled/cavity) is suitable for calibration of albedo TLD because of the good agreement with the energy/angular response of anthropomorphic phantom considered as equivalent to human body.

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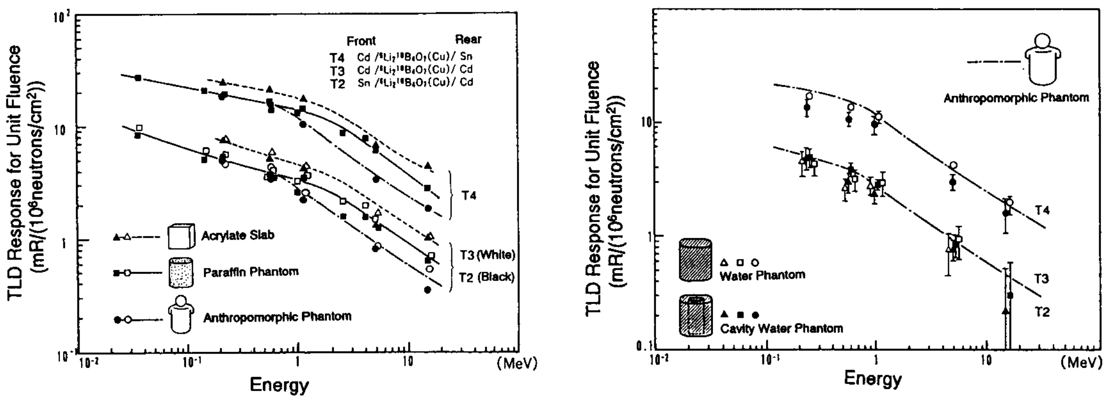
Table 1 Constitution of the TLD badge

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	$Cd/^{6}Li_2{}^{10}B_4O_7/Sn$

Table 2 Specification of the phantoms

Type of Phantom	General Usage	Shape, Size	Material	Remark
Paraffin Phantom	Calibration of Personal Dosimeters	Capsular Cylinder 40X30X20cm	Paraffin 0.9g/cm³	
Acrylate Slab	Calibration of Personal X,γ Dosimeters	Slab 40X40X15cm	Methyl Methacrylate Resin (JIS K6718) 1.19g/cm3	JIS Z4331
Water Phantom	Test of X ray tube for Diagnosis	Elliptical Cylinder 46X30X20cm	Water	JIS Z4915
Cavity Water Phantom	Test of X ray tube for Diagnosis	Elliptical Cylinder 46X30X20cm	Water	JIS Z4915
Anthropomorphic Phantom	Test of Personal Neutron Dosimeters	Average Japanese Man	Tissue:ICRU solution Lung:Kyoto Kagaku LP-430 Bone:Kyoto Kagaku BE-204	



(a) (b)

Figure 1 TLD energy response on the phantoms

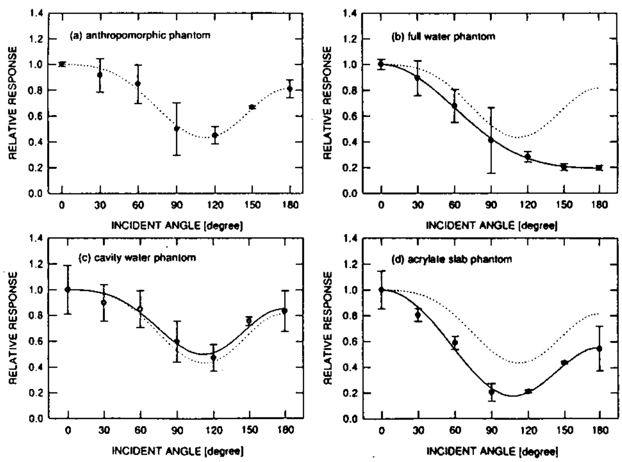


Figure 2 TLD angular response on the phantoms