Application Test of Element Correction Factors and Dose Conversion Factors for Extremity Dosimetry at Korean Nuclear Power Plants

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1. Introduction

Korean nuclear power plants (NPPs) have provided continuously several measures to reduce the occupational radiation exposure to optimum levels. In particular, since the concern about radiation protection has been increased by NPP workers, the development of technology to measure and to estimate the extremity dose of radiation workers has been demanded. In terms of extremity dosimetry, Korea Electric Power Research Institute (KEPRI) has performed the research project, development on the technology at radiation extremity dose measurement and assessment for atomic radiation workers at NPPs, to provide the technical backgrounds and criteria for extremity dosimetry [1].

In this paper, the calculation process of element calibration factors (ECFs) and radiation response for thermoluminescent dosimeters (TLD), especially extremity dosimeters, was briefly reviewed; then, ECFs and dose conversion factors (DCFs) for two types of extremity dosimeters, Harshaw EXTRAD dosimeters and Panasonic UD-807 dosimeters, which are currently available at Korean NPPs, were calculated by calibration and irradiation tests. Finally, the application of ECFs and DCFs to extremity dosimetry for radiation workers in Korean NPPs was investigated.

2. Methods and Results

2.1 ECF calculation process

ECF is defined as a response ratio of an element of each TLD to average of response values of each element of reference TLD [2,3].

$$ECF = e(i, j) / EM(i)$$

Here, $e(i,j)$ is a response value of element 'i' of TLD(j) for radiation exposure and $EM(i)$ is an average response value of element 'i' of reference TLD for radiation exposure. The ECF calculation process for extremity dosimeters is the same as that of whole body dosimeters except that extremity dosimeters have just one thermoluminescent element [2-4].

2.2 ECF calculation results

To obtain ECF, 400 EA of Harshaw EXTRAD dosimeters and 500 EA of Panasonic UD-807 dosimeters were analyzed. EXTRAD and UD-807 dosimeter use lithium fluoride and lithium borate as thermoluminescent materials, respectively. The reading of radiation exposure was performed using Harshaw TLD Reader Model 8800 Plus and Panasonic UD-716 TLD Reader. The ECF distributions are shown in Figures 1 and 2 for EXTRAD and UD-807 dosimeters, respectively.

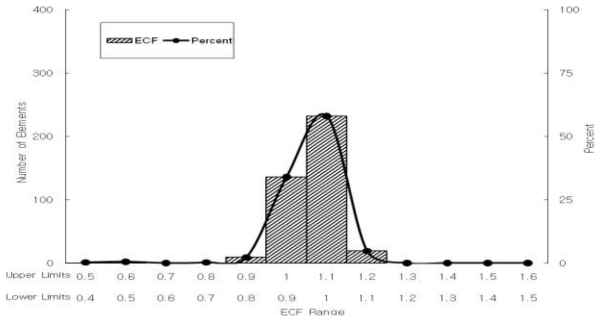

Fig. 1 ECF Distribution for EXTRAD Dosimeters

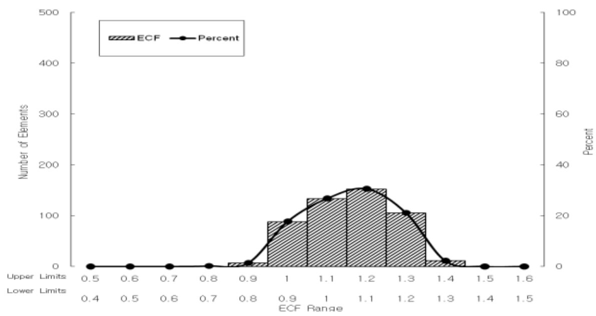

Fig. 2 ECF Distribution for UD-807 Dosimeters

2.3 DCF calculation process

For photons, the dose equivalent assigned to exposed extremity dosimeters is calculated using the exposure-to-dose conversion factors (C_x) [5]. The shallow absorbed dose (D_s) or the dose equivalent (H_s) for radioactive source irradiation is calculated by:

$$D_s = C_x \times X_{air} \times t \quad \text{or} \quad H_s = Q \times C_x \times X_{air} \times t$$

Here, Q is the quality factor, X_{air} is the exposure rate (R/time) in air, and t is the irradiation time.

For beta particles, the dose equivalent (H_s) assigned to exposed dosimeters is calculated using

$$H_s = D_1(d) \times t \times Q$$

Here, $D_1(d)$ is the absorbed dose rate at the calibration depth d.

Table 1 Response Calculation Results for Various Standard Radiations

Beam Code	ANSI (N13.32-1995)	KAERI	Harshaw EXTRAD		Panasonic UD-807	
	Finger Phantom	Finger Phantom	KEPRI	Manufacturer	KEPRI	Manufacturer
High-energy photon (^{137}Cs)	0.98	0.98	0.86	1.00	0.87	0.94
X-ray						
M30 (20 keV)	0.95	0.95	0.84	-[a]	0.60	0.45
M60 (35 keV)	0.98	0.98	1.04	-[a]	0.68	0.72[b]
M100 (53 keV)	0.99	1.01	1.13	-[a]	0.69	0.77[c]
M150 (73 keV)	1.01	1.03	1.01	-[a]	0.69	0.84[d]
Beta-ray ($^{90}Sr/^{90}Y$)	-	-	1.04	-[a]	1.08	1.19

[a] Manufacturer does not provide the response data for EXTRAD dosimeters expect high-energy photon radiation.

[b,c,d] Manufacturer uses slightly different radiation fields for response calculation of dosimeters from those of ANSI 13.32-1995 (b: 30 keV, c: 50 keV, d: 70 keV).

2.4 DCF calculation results

To obtain DCF, the irradiation tests were performed using reference photon and beta radiation fields at Korea Atomic Energy Research Institute (KAERI), which provides the same beam codes referred by American National Standard Institute (ANSI) with an error of less than 2 % [6]. In irradiation, the finger phantom was used, which was a solid, circular cylinder constructed of polymethylmethacrylate(PMMA), having a diameter of 19 mm and a length of 300 mm.

The irradiation tests were conducted two times for each Harshaw EXTRAD dosimeter and Panasonic UD-807 dosimeter. The number of test dosimeters was 72 EA and 108 EA(54 EA x 2 Groups) for EXTRAD dosimeters and 72 EA and 54 EA for UD-807 dosimeters, respectively. Table 1 demonstrates the results of irradiation tests. DCFs suggested by ANSI and KAERI are also showed in Table 1 for comparison.

2.5 Radiation Field Characteristics for Workplaces that have High Radiation Exposure in NPPs

In previous study, the incident radiation fields were analyzed using TLD readouts during the maintenance of inhomogeneous radiation fields [7]. Field tests where workers wore TLD on the chest and back and wore additional TLD on the wrist and extremity dosimeter on the finger were also conducted. TLD on the wrist and extremity dosimeter on the finger were used to analyze radiation fields and to estimate the extremity dose, respectively. As a result of the analysis of the TLD readouts from the TLD on the wrist, it was discovered that the TLD readouts from each element were almost similar and it was found that the incident radiation field to the fingers was a high-energy photon. Thus, it was concluded that the risk of non-penetrating radiation, such as beta ray, is low for NPP workers because the incident radiation originated from the high-energy photons [7].

3. Conclusions

In this study, ECFs and DCFs for extremity dosimetery at Korean NPPs were calculated by calibration and irradiation tests results. As a result of ECF calculation, the response ratios for Harshaw EXTRAD dosimeters were almost within the range of 10 % and it is regarded that it is possible to use Harshaw EXTRAD dosimeters for measurement of extremity dose without the compensation of ECF. In case of Panasonic UD-807 dosimeters, ECFs are distributed from 0.9 to 1.3 and it is also regarded that it is not necessary for the compensation of ECF if UD-807 dosimeters which have good ECF (within 10% of range) are used for extremity dosimetry.

Irradiation test results showed that DCFs for high energy photons are within the range of 10 % for both Harshaw EXTRAD dosimeters and Panasonic UD-807 dosimeters. In previous study, the radiation fields for workplaces that have high radiation exposure in NPPs are dominated by high energy photons. Thus, it can be regarded that the contributions of DCFs for extremity dosimetry in NPPs is trivial.

In conclusion, above two reasons, small deviation of ECFs and DCFs of extremity dosimeters and radiation fields of high energy photons in NPPs, it is not necessary to apply ECFs and DCFs for extremity dosimetry in NPPs.

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