Upgrading of personal dose evaluation with electronic personal dosemeters for nuclear power plants

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1. Introduction

In the past, workers had to wear multiple dosemeters for different purposes in order to work in radiation controlled areas in nuclear power plants in Japan. The three specific objectives are shown below:

(1) Dosemeter for dose evaluation for a period of one day, quarter year, one year, and five years, to comply with the requirements of laws and regulations;

(2) Dosemeter for dose control for a period of a day and each occasion of entering a controlled area, in order to perform more detailed control;

(3) Dosemeter with an alarm function to prevent excess exposure.

In order to reduce the burden on wearers caused by using multiple dosemeters and to rationalize dose control, the Japan Atomic Power Company conducted joint research with partner companies for the purpose of unifying the dose control using only electronic personal dosemeters. In 1997, we developed and introduced an electronic personal dosemeter that conforms with all the purposes described above, and after two years of evaluation, the unification of dose control with the electronic personal dosemeters for nuclear power plants in Japan was achieved for the first time in 2000.

In 2008, about ten years later, the electronic personal dosemeter was upgraded in response to worker demands and to improve the level of management by radiation supervisors at contracting companies.

The history of development of the personal dosemeter follows the history of the Japan Atomic Power Company as described below.

2. History of personal dose control

The Japan Atomic Power Company started commercial operation of the Tokai Power Station (GCR), which was the first commercial nuclear power plant in Japan, in 1966, followed by the Tsuruga Power Station Unit 1 (BWR), which was the first commercial light-water nuclear reactor in Japan, in 1970, the Tokai No. 2 Power Station (BWR) in 1978, and the Tsuruga Power Station Unit 2 (PWR) in 1987.

The history of our company that consists of the creation period of the nuclear plant in Japan, is the history of the personal dose control, and is the epitome the transition of the personal dose control, too.

When the Tokai Power Station started commercial operations, personal dose control was initiated using two kinds of dosemeter: one is a film batch (hereinafter called FB) as a dosemeter for evaluation and the other is an pocket dosemeter of ionization chamber method (hereinafter called PD) for dose control on a daily basis and for each occasion of entering controlled areas. PD wasn't possible to hold its dose because of direct-reading type, the personal dose control was done by a hand everyday by recording the reading dose values in a notebook at each occasion of entering controlled areas.

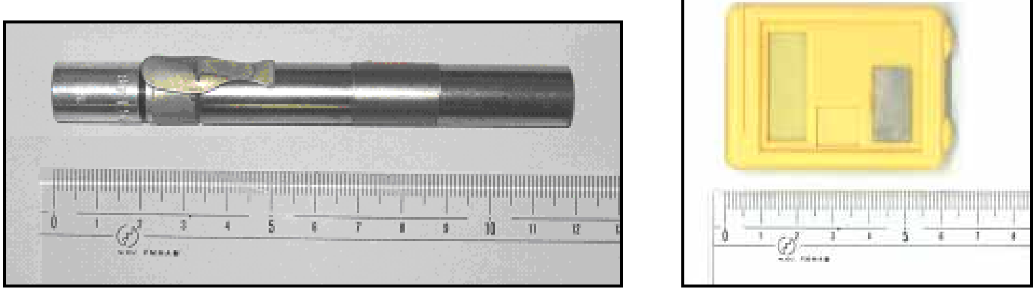

Fig. 1 Chamber-type pocket dosemeter (left) and film batch (right)

After the start of commercial operations of the Tsuruga Power Station Unit 1 in 1970, we started using a personal dosemeter of electric method with an alarm function (hereinafter called APD) to prevent excess exposure, in addition to the FB and PD mentioned above. The three elements required for personal dose control started at that time.

In 1971, since the FB takes a long time to determine the dose, we started using a thermoluminescence dosemeter (hereinafter called TLD) instead of the PD.

Fig. 2 Personal dosemeter with alarm function (left) and thermoluminescence dosemeter (right)

Subsequently, in 1978, at the start of commercial operations of the Tokai No. 2 Power Station, the automatic reading type thermoluminescence dosemeter (hereinafter called ATLD) was introduced for dose control for a period of a day and each occasion of entering a controlled area, and thereby replaced the PD and TLD.

On this occasion, access control gates that automatically read the ATLD data were installed at each entrance of controlled areas. And we constructed the automatic personal dose control system in our host computer. It was managing the personal dose by collating and totaling a dose read from ATLD and by recording each dose on ID card. This system made it possible to automatically perform the timely personal dose control.

Fig. 3 Thermoluminescence dosemeter (left), access control gate (center), and operating section (right)

In 1989, in order to reduce the burden on wearers caused by using multiple dosemeters and to rationalize dose control, we started basic research on the unification of dose control. Subsequently, with the improved reliability of electronic equipment and performance of calculating machines, we focused on unifying dose control by means of electronic personal dosemeters. In 1992, we began conducting collaborative research with several electric power companies as well as manufacturers of electronic personal dosemeters. After consideration of practical use of electronic personal dosemeters with Nuclear Services Company and Fuji Electric Systems Co. Ltd., we developed and introduced the dosemeters in 1997 and discontinued the ATLD and APD.

We presently have two types of electronic personal dosemeters (hereinafter called E.P.D.) for use depending on exposure and operation conditions: a special type for gamma rays that was developed by pursuing reduced size and weight, and a multifunctional type that can simultaneously measure gamma rays, beta rays and neutrons. Radiation characteristics of the two types are equivalent to those of the FB used as a dosemeter for evaluation.

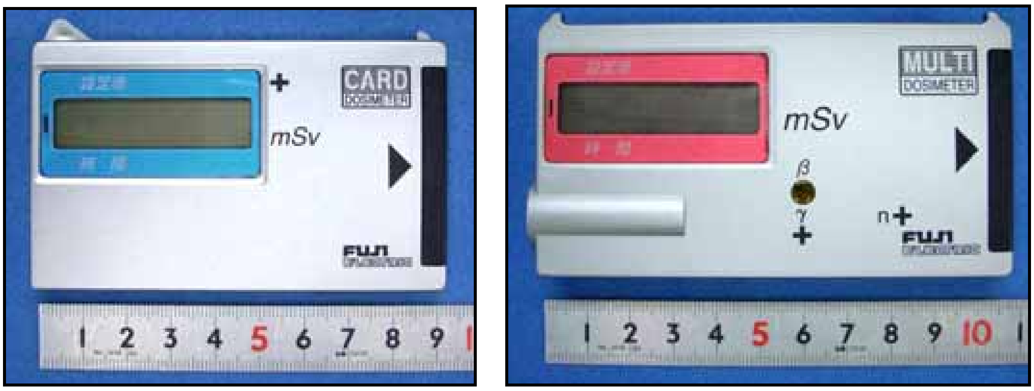

Fig. 4 Electronic personal dosemeter (left: for gamma rays, right: for gamma rays + beta rays + neutrons)

Additionally, the access control system for controlled areas was updated.

Although the ATLD system can only add the measured dose values and control the dose for a period of a day, the E.P.D. system enables real-time checking of the alarm level set for each operation and the dose for a period of one day, quarter year, one year, and five years.


Fig. 5 Access control gates for electronic personal dosemeters for controlled areas

For two years after its introduction, the E.P.D. was used in parallel with the FB to confirm comparable performance. External experts evaluated the characteristics of the E.P.D. and confirmed that it could be used as an evaluation dosemeter without a problem. Therefore, in 2000, we discontinued the FB and achieved unification of personal dose control with the E.P.D.

	1960 –	1970 –	1980 –	1990 –	2000 –
(1) Dosemeters for evaluation					
(2) Dosemeters used for dose control for a period of a day and each occasion of entering a controlled area					
(3) Dosemeters with alarm function					

Table 1 History of personal dosemeters

3. Sophistication of personal dose control

About ten years after introducing the E.P.D., it became increasingly difficult to secure the maintenance parts and we received numerous worker demands for improvement. In addition, Japanese Industrial Standards (hereinafter called JIS) concerning the E.P.D. have since been specified. To respond to these internal/external demands, we upgraded the E.P.D in 2008.

In the upgrade, we tried to increase the level of sophistication of functions, etc. for the three items shown below, following the concept of the existing E.P.D.:

▪ Enhancing the inherent performance of the E.P.D., such as radiation characteristics;
▪ Improving the usability and reliability by incorporating the worker demands for improvement;
▪ Adding functions aimed at improving the level of management by radiation supervisors at contracting companies.

(1) Enhancing the inherent performance of the E.P.D., such as radiation characteristics

As shown in Table 2, our E.P.D. has radiation performance conforming to JIS Z4312 "Direct reading personal dose equivalent (rate) meters and monitors for X, gamma, beta and neutron radiation."

Item		JIS		Equipment specification of E.P.D.
		Grade	Allowance (Range)	Allowance (Range)
Energy characteristics	Gamma ray	EP2	± 30% (60 keV to 1.5 MeV)	± 20% (60 keV to 6 MeV)
	Beta ray	EB1	± 30% (500 keV to 2.2 MeV)	± 30% (500 keV to 2.2 MeV)
	Neutron	EN1	± 50% (thermal neutron to 15 MeV)	± 50% (100 keV to 2.3 MeV)
Directional characteristics	Gamma ray	AP1	± 20% (0° to ± 60°, in steps of 15°)	± 20% (0° to ± 60°, in steps of 15°)
	Beta ray	AB1	± 30% (0° to ± 60°, in steps of 20°)	± 30% (0° to ± 60°, in steps of 20°)
	Neutron	AN1	± 30% (0° to ± 75°, in steps of 15°)	± 30% (0° to ± 75°, in steps of 15°)
Dose rate characteristics	Gamma ray	R1	± 20% (max. 1 Sv/h)	± 20% (max. 1 Sv/h)
	Beta ray	R1	± 20% (max. 1 Sv/h)	± 20% (max. 1 Sv/h)
	Neutron	R2	± 20% (max. 100 mSv/h)	± 20% (max. 100 mSv/h)
Temperature characteristics		T2	± 20% (0°C to 40°C)	± 20% (0°C to 40°C)
Drop characteristics		D1	± 10% (6 faces for each 1.5 m and 0.1 m)	± 10% (6 faces for each 1.5 m and 0.1 m)
Alarm characteristics		B2	100 dBA or more (at 20 cm)	100 dBA or more (at 20 cm)
Dose hold		Grade 1	Recorded information is not deleted even if the power is turned off.	Recorded information is not deleted even if the power is turned off.

Table 2　Basic radiation characteristics

Fig. 6　Advanced E.P.D. (left: for gamma rays, right: for gamma rays + beta rays + neutrons) and dose display

(2) Improving the usability and reliability by incorporating worker demands for improvement

In order to incorporate the demands from workers for checking the dose without taking the E.P.D. from their pocket during operation, we designed the device so that the dose is displayed as shown in Fig. 6.

In the existing special type for gamma rays, the alarm sound is low because of its miniaturization. In response to many demands for an alarm volume as loud as that of the multifunctional type, we achieved this in the new E.P.D.

To improve the reliability, we reviewed the external case and internal structure in order to satisfy the noise resistance performance related to JIS, such as external electromagnetic field characteristics, electrostatic discharge characteristics, and shock resistance, as well as improve the noise resistance performance concerning PHS, welding machines, etc. that had been a problem in the power plants.

Additionally, we multiplexed the communication measure for the access control gates in the controlled areas, changing it from extremely low power radio alone to specified low power radio + infrared ray + contacts, in order to eliminate imperfect communication when passing through the gates.

(3) Adding functions aimed at improving the level of management by radiation supervisors at contracting companies

The main function of personal dosemeters for preventing excess exposure is the alarm sound of the APD, and the supplementary functions are the earphones, external buzzer, external display for indicating dose outside the clothes, etc.

While these existing functions indicate dose values to the person wearing the E.P.D., we have now introduced a wireless monitoring system in which radiation supervisors can also monitor exposure conditions during operation in real time.

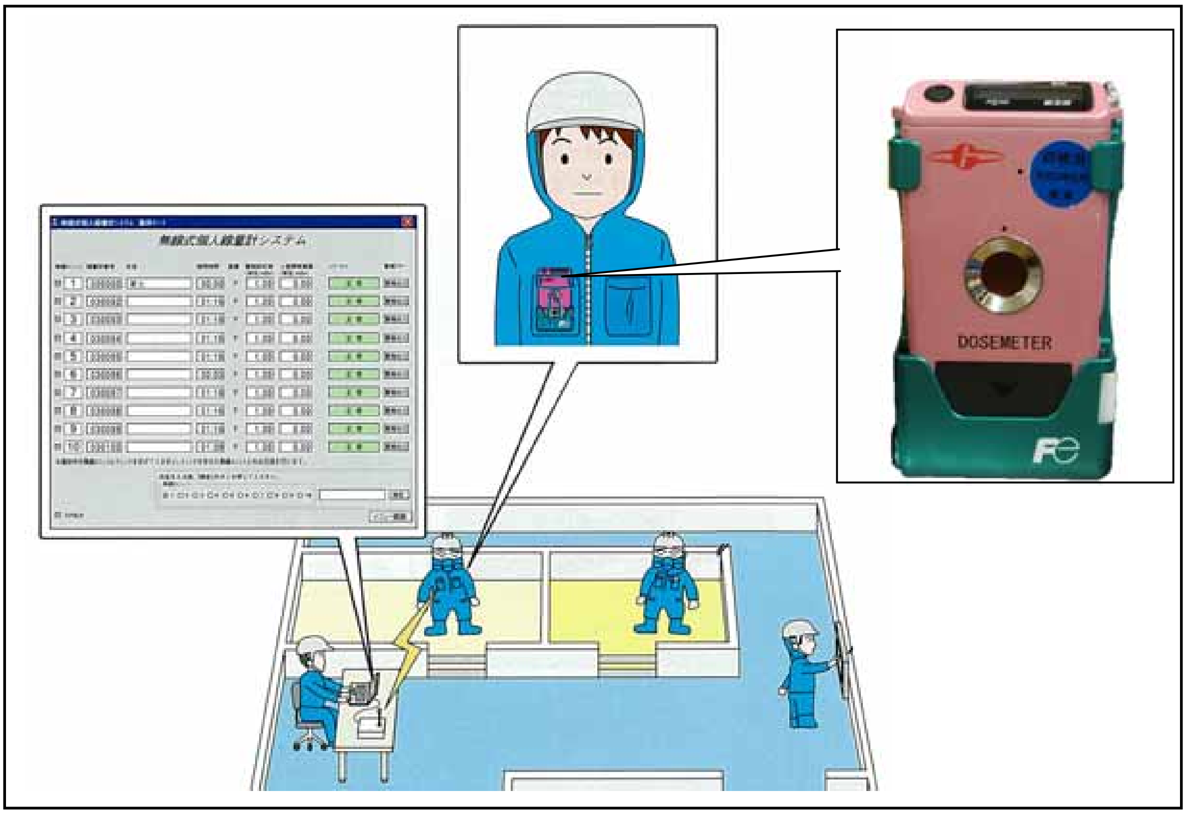

Fig. 7 Conceptual diagram of wireless monitoring system

Exposure conditions are indicated on the monitor terminal by installing the wireless monitoring unit in the E.P.D., which enables wearers to work without relying on the alarm and radiation supervisors to securely monitor the dose. In addition, this leads to a reduction in exposure to the radiation supervisors themselves because they need not stay near the working areas.

Furthermore, since trend collection of E.P.D. measured values is constantly performed by a minimum of one minute and after use, the data is collected by a dedicated charger while charging the battery, and analysis of exposure conditions after operation can be performed.

4. Summary

The Japan Atomic Power Company has adopted personal dosemeters suited to the times in order to respond to different needs. We recently adopted electronic personal dosemeters in which the three elements for personal dose control are unified.

In the new model, the quality of radiation control at contracting companies has been improved by responding to worker demands, for example changing the location of the dose display to the top part, and changing the alarm volume of the special type for gamma rays to the same volume as that of the multifunctional type, as well as adopting real-time monitoring by means of a wireless monitoring function.

In the future, we would like to utilize the measured data collected for various purposes in order to contribute to a method for reducing exposure.