Portable Radiation Monitor

Kaoru Masui
Takeshi Ishikura
Daisuke Inui

1. Introduction

At nuclear power plants, research facilities, hospitals and the like in Japan, portable radiation monitors that can be carried by workers are used commonly as simple radiation monitors for everyday use. Also outside of Japan, the increasing number of nuclear power plants and facilities that utilize radiation is expected to lead to greater demand for portable radiation monitors. This paper presents an overview of portable radiation monitors and introduces new model types that have been developed in recent years.

2. Types and Uses of Portable Radiation Monitors

Types of portable radiation monitors include survey meters, portable monitoring posts that measure γ-ray dose rates, environmental dosemeters that measure an accumulated dose at the border of a radiation controlled area, and the like. Survey meters can be classified as γ-ray survey meters that measure γ-ray dose rates, neutron rem counters that measure neutron (n) dose rates, and β-ray survey meters that measure surface contamination on people and articles. Table 1 lists the main products and their specifications.

The ionization chamber survey meter (NHA100) is able to measure 1 cm dose equivalent rates with good accuracy over a wide energy range. Moreover, this small, lightweight and easy-to-use survey meter can measure instantaneous X-ray doses, and by removing the front surface cap of the ionization chamber, is capable of detecting β-rays (Fig. 1). Main specifications of the ionization chamber survey meter are listed in Table 2.

The Geiger-Muller (GM) survey meter (NHJ110) employs a highly sensitive GM counter, and is used for simple detection of radiation leakage at nuclear facilities. Moreover, the NHJ120 of the same series is a survey meter for surface contamination measurement using an end-window type 50 mm-diameter GM counter, and is capable of measuring β-ray surface contami-

Fig.1 Ionization chamber survey meter

Table 1 Main types of portable radiation monitors

Product name	Model	Type of radiation measured				Energy (keV)					Measurement range							Units
		β	γ	n	X	10^0	10^1	10^2	10^3	10^4	10^{-2}	10^{-1}	10^0	10^1	10^2	10^3	10^4	
Ionization chamber survey meter	NHA100	○	○		○													μSv/h
Wide energy range X/γ ray survey meter	NHC510		○		○													
GM survey meter	NHJ110		○															
Neutron rem counter	NSN100			○														
GM survey meter	NHJ120	○																Bq/cm²
Portable monitoring post	–		○															nGy/h
Environmental dosemeter (accumulated)	NSD2		○		○													mSv

Table 2 Specifications of ionization chamber survey meter

Item	Specifications
Detector	Ionization chamber detector
Measurable radiation	X-ray, γ-ray and β-ray
Energy range	X-ray, γ-ray: 25 keV to 3 MeV
Measurement range	Dose equivalent rate: 1 μSv/h to 30 mSv/h Instantaneous dose equivalent rate : 0.1 to 10 μSv
Measurement accuracy	Within ±10 %
Energy response	Within ±20 % (25 keV to 3 MeV)
Ambient temperature	0 to 40°C
Dimensions	Approx. 106 (W) × 200 (D) × 210 (H) (mm)
Mass	Approx. 1 kg
Continuous operation time	100 hours or more at normal temperature
Power supply	C battery × 5

Fig.2 GM survey meter

Fig.3 Neutron rem counter

nation (Fig. 2). Specifications of the GM-type survey meter are listed in Table 3.

The neutron rem counter (NSN100) is a survey meter for measuring the neutron dose equivalent rate in a nuclear facility, accelerator or other leakage neutron field. The detector response has been designed to match the rem response listed in the ICRP51 (Data for use in protection against external radiation) publication by the International Commission on Radiological Protection (ICRP), and dose equivalent values can be read directly. The neutron rem counter made by Fuji Electric features extremely high sensitivity and a light

Table 3 Specifications of GM survey meter

Item	Specifications	
Detector	GM detector	
Measurable radiation	γ (β)-ray	β (γ)-ray
Energy range	60 keV to 1.5 MeV	–
Measurement range	Dose rate : 0.0 to 300.0 μSv/h Count rate : 0 to 99.99 × 1000/min	Count : 0 to 9999 k counts Surface contamination density : 0 to 9999 Bq/cm^2 Count rate : 0 to 99.99 k/min
Measurement accuracy	Dose rate : within ±20 % Count rate : within ± 3 %	Count rate : within ±3 % Surface contamination density : depends on measurement conditions
Energy response	Within ±50 % (60 keV to 1.5 MeV) (Dose equivalent rate H*(10))	–
Angular response	Within ±20 % (0 to ±60°C)	–
Counting efficiency	–	30 % or more (U_3O_8 : 10 cm × 10 cm radiation source, distance to the detector : 5 mm)
Ambient temperature	−5 to +45°C	
Dimensions (mm)	Approx. 98 (W) × 227 (D) × 145 (H)	Approx. 98 (W) × 227 (D) × 170 (H)
Mass	Approx. 1.3 kg	
Continuous operation time	100 hours or more (alkaline AA battery), 20 hours or more (rechargeable battery)	
Power supply	Alkaline AA battery × 6 or rechargeable battery	

Table 4 Specifications of neutron rem counter

Item	Specifications
Detector	^{3}He proportional counter
Measurable radiation	Neutrons
Energy range	0.025 eV to 15 MeV
Measurement range	Dose rate : 0.01 μSv/h to 9.999 mSv/h Dose : 0.001 μSv to 9.999 mSv
Measurement accuracy	Dose rate : within ±15 % at 1 μSv/h Dose : within ±25 % at 0.005 μSv
Energy response	ICRP51 compliant
Angular response	Within ±10 % (0 to ±135°, ^{252}Cf)
Neutron sensitivity	4.5 s^{-1}/μSv/h ±20 % (^{252}Cf)
Ambient temperature	−10 to +45°C
Dimensions	Approx. 210 (dia.) × 320 (mm)
Mass	Approx. 7 kg
Continuous operation time	More than 12 hours (C battery)
Power supply	AC power, C battery × 2, rechargeable battery (option)

weight. A ^{3}He proportional counter is used to improve the sensitivity, and the construction of the neutron moderator that covers the detector is optimized to achieve a lighter weight (Fig. 3). Table 4 lists the specifications of the neutron rem counter.

The recently developed wide energy range X/γ survey meter (NHC510), the environmental dosemeter system, and the portable monitoring post (NAJ5) are introduced below.

3. Wide Energy Range X/γ -ray Survey Meter

3.1 Overview

X-ray generators are now used in various applications such as medical field, and at the facilities where they are used, there is a need for survey meters capable of measuring leakage doses from low energy X-rays to environmental γ-rays (γ-rays of approximately 1.5 MeV or less). The energy of X-rays emitted from an X-ray irradiator used for medical purposes is at least 8 keV, and in consideration of this range, Fuji Electric developed a survey meter capable of highly sensitive and accurate 1 cm dose equivalent measurements in the 8 keV to 1.5 MeV region (Fig. 4).

During the development stage, in order to efficiently measure low energy photons while ensuring the angular response when measuring environmental γ-rays, the dimensions of the NaI (T*l*) scintillator and the material and thickness of the storage case were optimized. Also, energy compensation and temperature compensation functions were provided to realize good performance characteristics. The energy characteristics are shown in Figs. 5 and 6. A 1 cm dose equivalent response within ±25 % was realized for the range from 10 KeV to 200 keV in the X-ray mode and for range from 50 keV to 1.5 MeV in the γ-ray mode.

3.2 Characteristics and specifications

The characteristics are listed below.

(1) Measurement with high sensitivity is possible for the wide energy range from 8 keV (X-rays) to 1.5 MeV (environmental γ-rays)

Fig.4 Wide energy range X/γ-ray survey meter

(2) An energy compensation function enables accurate measurement of 1cm dose equivalent rates.

(3) Measurement results are easily verified with a 4-digit digital display and a bar graph indicator

Fig.5 Energy response (X-ray mode)

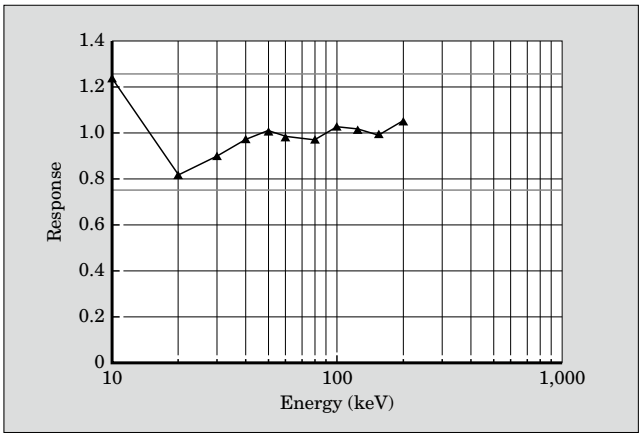


Fig.6 Energy response (γ-ray mode)

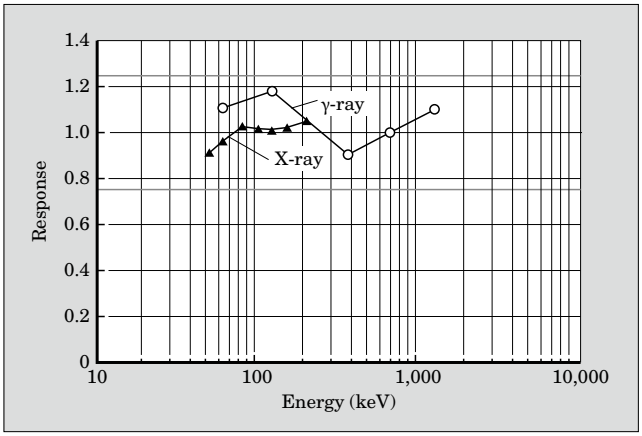


Table 5 Specifications of wide energy range X/γ-ray survey meter

Item	Specifications
Detector	NaI scintillator, 12.7 (dia.) × 12.7 (mm)
Measurable radiation	X-ray, γ-ray
Energy range	X-ray : 8 to 300 keV γ-ray : 50 keV to 1.5 MeV
Measurement range	X-ray : BG to 60 μSv/h (^{241}Am reference) γ (X)-ray : BG to 60 μSv/h (^{137}Cs reference)
Measurement accuracy	Within ±20 %
Energy response	X-ray : within ±25 % (10 keV to 200 keV) γ (X)-ray : within ±25 % (50 keV to 1.5 MeV)
Angular response	Within ±20 % (0 to ±90°)
Ambient temperature	0 to 40°C
Dimensions	Approx. 100 (W) × 215 (D) × 155 (H) (mm)
Mass	Approx. 1.3 kg
Continuous operation time	More than 8 hours (C battery)
Power supply	C battery × 6 Rechargeable battery (option) AC power (option)

display.

(4) Operation is switchable between an "X-ray mode" for low energy X-ray measurement and a "γ-ray mode" for measurement of up to 1.5 MeV.

(5) The meter has a small size and is lightweight, portable, and easy to use.

(6) A temperature compensation circuit is provided.

Table 5 lists the main specifications.

4. Environmental Dosemeter System

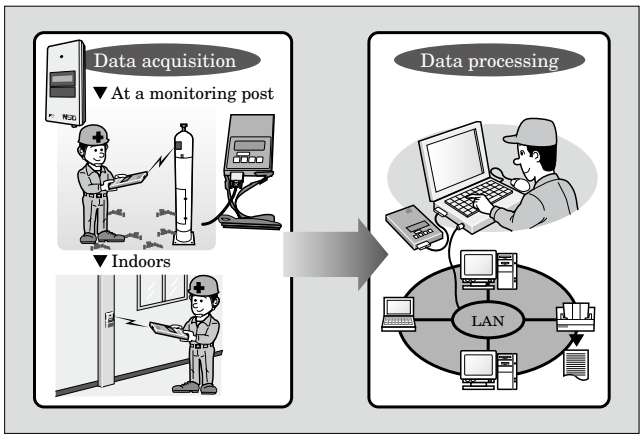
4.1 Overview

At nuclear power plants and other facilities that use radiation, the γ-ray total dose is measured and recorded at the boundaries of the controlled areas, at workplaces in radiation controlled areas, and in the surrounding areas. Previously, thermoluminescent dosemeters have been used for this purpose, but those dosemeters must be collected and relocated, dose rate trends cannot be recorded, and the read out process was complicated and required annealing.

To satisfy the abovementioned need, Fuji Electric applied its personal dosemeter technology, having been refined over many years of development, to develop an environmental dosemeter system configured from an environmental dosemeter, a data acquisition terminal and a data processing computer. Figure 7 shows an overview of the environmental dosemeter system. An environmental dosemeter system is installed at each measurement site and measures dose rate trends and accumulated doses, and the measurement data is acquired periodically using a small size, light weight and portable data acquisition terminal. The acquired data is transferred via a RS-232C cable to a data processing computer, and the data can easily be stored, referenced and processed. With this method, there is no need to collect or relocate the dosemeters, and the acquisition of data is easy to implement.

During development of the environmental dosemeter, in order to enable measurement of doses due to the normal background (BG) level (approximately 0.001 mSv or greater), the sensor was enlarged and the electrode structure was optimized to increase the sensitivity of the semiconductor detector. Accordingly, measurement accuracy of within ±10 % was realized for dose values of 0.01 mSv or greater. Additionally, a low current consumption circuit was developed so that the environmental dosemeter could be used continuously for at least one year. In order to prevent data loss due to a power failure, the environmental dosemeter continuously stores measurement data in a non-volatile memory (EEPROM). Furthermore, a battery voltage drop sensing function and a count circuit self-diagnostic function ensure good reliability. This environmental dosemeter system is widely used at present in Japanese nuclear power plants and the like as a substitute for thermoluminescent dosemeters.

Fig.7 Process flow for an environmental dosemeter system



4.2 Characteristics and specifications

Features of the environmental dosemeter (NSD2) are listed below.

(1) Sensitive to background level doses and capable of accurate measurement.

(2) Can operation continuously for at least one year.

(3) Is provided with a non-contact communication (infrared communication) function to a data acquisition terminal.

(4) Stores measurement data in a non-volatile memory so that measurement data can be read even in the case of a failure.

(5) The main unit has a moisture resistant construction that is able to withstand water droplets

Table 6 Specifications of environmental dosemeter

Item	Specifications
Measurable radiation	γ (X) ray
Energy range	50 keV to 6 MeV
Measurement range	0.001 to 999.99 mSv
Measurement accuracy	Within ±10 % (0.01 to 10 mSv/h)
Energy response	Within ±30 % (60 keV to 6 MeV)
Angular response	Within ±20 % (horizontal : ±180°, vertical : +240 to −60°)
Trend data storage capacity	1,152 data points (max)
Communication specifications	Communication method : Infrared communications Contacting party : Data acquisition terminal Read time : Less than 2 sec (without trend data) Less than 10 sec (at max. number of trend data) Communication distance : 0 to 15 cm Communication speed : 9,600 bps Communication data : Accumulated dose, trend data, etc.
Ambient temperature	−10 to 50°C
Dimensions	Approx. 65 (W) × 20 (D) × 110 (H) (mm)
Mass	Approx. 140 g
Continuous operation time	More than 13 months
Power supply	Primary cell × 2

formed by condensation or the like.

The main specifications are shown in Table 6.

5. Portable Monitoring Post

5.1 Overview

At nuclear power plants and other such facilities, there is a need for simple environmental radiation monitors in order to supplement fixed-type monitoring posts and, in the case of an emergency, to assess quickly the dose rate at the periphery of the facility. Specific requirements are for accurate dose rate measurement over the wide measurement range from a background dose rate of 10 nGy/h to a dose rate during an accident of 10^3 nGy/h, and for easy transportation and measurement.

Typically in the past, two detectors were used according the dose rate, but in order to achieve lighter weight and a more compact size, Fuji Electric has developed a portable monitoring post that is capable of measuring the abovementioned range with a single detector. The detector is a NaI (T*l*) scintillator, and both pulse measurement and current measurement methods are used. The low dose rate region is measured in a pulse measurement mode and the high dose rate region is measured in a current measurement mode. Additionally, to ensure various characteristics such as the energy response over a wide range, the radiator shielding of the detectors is optimized, and an energy compensation circuit and a temperature compensation circuit are provided. Figure 8 shows the external appearance of the portable monitoring post.

5.2 Characteristics and specifications

Features of the portable monitoring post are listed below.

(1) A single detector supports dose rate measurement from the background level to high levels during an emergency.
(2) Small size and light weight facilitate transportation and installation.
(3) An all-weather model can be installed outdoors.
(4) Can operate with an external battery in locations where there is no AC power.
(5) An internal memory can store one week of measured data (one data value per minute).
(6) An energy compensation circuit and a temperature compensation circuit are provided.
(7) Data acquisition is performed with portable data acquisition devices or via (optional) cell phone communication or the like.

The main specifications are shown in Table 7.

6. Postscript

The portable radiation monitors introduced herein are being used at various facilities for a wide variety of purposes. In the future, Fuji Electric intends to continue to improve monitor performance and functionality, and to actively deploy these systems in overseas markets.

Fig.8 Portable monitoring post

Table 7 Specifications of portable monitoring post

Item	Specifications
Measurable radiation	γ-ray
Energy range	Low range region : 50 keV to 3 MeV High range region : 50 keV and above
Measurement range	10 to 10^8 nGy/h Low range region : 10 to 5×10^5 nGy/h High range region : 3×10^5 to 10^8 nGy/h
Measurement accuracy	±10 % (reference : for ^{137}Cs irradiation dose rate)
Angular response	±20 % (0 to ±90°)
Energy response	Low range region : ±20 % (50 keV to 100 keV) ±10 % (100 keV to 3 MeV) High range region : −50 % to +25 % (50 keV to 100 keV) −10 % to +20 % (100 keV to 400 keV) ±10 % (400 keV to 3 MeV)
Data acquisition method	With dedicated acquisition apparatus (serial communication)
Ambient temperature	−10 to +40°C
Dimensions	Approx. 440 (W) × 450 (D) × 740 (H) (mm)
Mass	Approx. 15 kg (without options)
Continuous operation time	Approx. 10 days (internal primary cell)
Power supply	100 V AC power supply, 12 V DC power supply, internal primary cell
Options	Wireless data acquisition, GPS

References

(1) Yamamura S. et al., Development of Low-energy γ-ray Survey-meter, KEK Proceedings, 2006-2.
(2) Yamamura S. et al,. Development of Wide-energy Range X/γ-ray Survey-meter, AOCRP-2 Proceedings, 2006-10, p. 322.