

Radioactive Contamination Monitor

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1. Introduction

At nuclear power plants, surface contamination inspection monitors are installed at the boundaries of radiation controlled areas in order to prevent radioactive contamination from spreading outside those radiation controlled areas, and all people exiting and all articles transported out of a radiation controlled area are monitored for surface contamination. The main types of surface contamination monitors include body surface contamination monitors that measure the surface contamination on a worker's body, article monitors that measure the surface contamination of tools and other articles carried by the workers, and laundry monitors that measure the surface contamination of worker's clothes and the like that have been worn in a radiation controlled area.

Additionally, there is also a hand-foot-clothes monitor that is used primarily at hospitals and the like to measure the surface contamination on hands, feet and clothes.

Using large-area radiation detectors, signal processing units capable of high-speed computational processing, mechanical devices capable of taking measurements under optimal conditions, and man-machine interfaces that utilize voice prompts and large-screen color LCDs to enable the measurement of radioactive matter with high sensitivity and at high-speed, Fuji Electric is delivering these systems to nuclear power plants and the like.

These systems are equipped with a self-diagnostic function and when connected to a data processing unit, enable the integrated control of contamination inspection and measurement data.

This paper presents an overview and describes the features of these surface contamination inspection systems.

2. Overview

In the past, gas flow proportional detectors were used in radiation contamination inspection systems, but in recent years, the various types of plastic scintillation detectors listed below have been developed in

accordance with each system application.

Plastic scintillation detectors have significant advantages for use and differ from the gas flow proportional detectors in that gas supply equipment is unnecessary, the safety of workers carrying gas canisters into a controlled area does not have to be ensured, and running costs are eliminated since no maintenance is required.

Fuji Electric has actively developed and commercialized larger sized plastic scintillation detectors for measuring people and articles in their entirety, without a decrease in detection sensitivity.

3. Body Surface Contamination Monitors

3.1 Overview

Installed at the exits from radiation controlled areas, surface contamination monitors inspect for the presence of contamination on the body surface of a person leaving a radiation controlled area. There are two types of body surface contamination monitors, a 1-step type that measures the main body surface areas in a single step, and a 2-step type that measures the front and back body surfaces in two steps. In Japan, the 1-step type is used in order to lessen the burden on the subject to be measured and out of consideration of the processing capability, and Fuji Electric has manufactured the 1-step type in response to this domestic need.

The 2-step type, having fewer detectors than the 1-step type and not requiring a driving unit, is in demand overseas since it can be manufactured at lower cost, and Fuji Electric will actively manufacture the 2-step type in the future.

3.2 Features

(1) Detection sensitivity

Beta-rays can be measured with a sensitivity of 0.4 Bq/cm^2 .

(2) Detector

Large-size plastic scintillation detectors are used for beta-rays.

(3) Measurement locations

Head: In order to measure with good sensitivity, the measurement location is raised from

1,300 mm to 2,000 mm automatically according to the height of the subject.

Hands and feet:

Right hand, left hand, back of right foot, and back of left foot can be measured individually.

Sensors are located at the measurement areas, and the measurement starts automatically when the subject sets their hand or foot in the measurement location.

Front and back surfaces:

3 large area detectors are positioned at the front and back, and provide coverage of heights of up to 2,000 mm.

Side surfaces:

2 large area detectors are positioned on the

left and right sides, and provide coverage of up to the subject's shoulders.

Moreover, the detectors on either side have doors that open and close automatically and function as gates which, in the case of contamination, prevent a subject from leaving the radiation controlled area and entering a non-radiation controlled area.

(4) Operation functions

Usually, the measuring process is performed for a certain amount of time (settable according to the operation), but the measurement time may be computed automatically according to the monitor type so that the measurement is performed in a shorter amount of time.

3.3 Transportable body surface contamination monitor

Surface contamination monitors are usually stationary monitors that are affixed to the floor, but a type that may be transported easily for disassembly and assembly is introduced below.

This transportable monitor is provided with detectors to cover the same entire body surface as the stationary type and also has the same functions and performance as the stationary type. Figure 1 shows the external appearance and Table 1 lists the specifications of the transportable body surface contamination monitor.

3.4 Convenient body surface contamination monitor

The number of detectors installed can be customized according to the status of radiation contamination of the facility. The monitor shown in Fig. 2 is installed inside a radiation controlled area, and detectors are positioned at the hands and feet, and body sides and front surfaces where there is a high frequency of contamination, so that preliminary measurements can be carried

Fig.1 Transportable body surface contamination monitor



Table 1 Specifications of the transportable body surface contamination monitor

Item	Specification
Detector	Plastic scintillation detector
Detector positioning	Front and back surfaces (top, middle, bottom) Left and right side surfaces (top, middle, bottom) Head, right hand, left hand, right foot, left foot ; Total 17 surfaces
Detector sensitivity <Measurement conditions> BG Measurement time Radiation source Measurement distance	0.4 Bq/cm ² 0.1 μSv/h 10 s ⁹⁰ Sr 100 mm × 100 mm Hands and feet : Close contact Head : 50 mm Other : 100 mm
Processing capacity	Approx. 20 s
Size (W) × (D) × (H)	860 × 1,000 × 2,250 (mm)
Mass	780 kg

Fig.2 Convenient body surface contamination monitor



out within a short amount of time. A worker enters the monitor from the backside of the monitor, and sets his/her hands and feet at the measurement location to start the measurement easily and automatically.

4. Article Surface Contamination Monitors

4.1 Overview

Article transfer monitors inspect for contamination on the surface and interior of articles transferred out from a radiation controlled area. These monitors are capable of measuring many articles at once and can operate while a worker is being measured by a body surface contamination monitor so as to reduce the amount of labor required. A small article transfer monitor and a transportable small article monitor (types 1 and 2) are available according to the dimensions and weight of the articles to be measured. Figures 3 to 5 show the appearance of each.

Fig.3 Small article transfer monitor



Fig.4 Transportable small article monitor (type 1)



4.2 Common characteristics

(1) Detection sensitivity

Beta-rays and gamma-rays are measurable with sensitivities of 0.4 Bq/cm² and 1.1 Bq/cm², respectively. The measurement conditions are listed in Table 2.

(2) Positioning of detectors

To measure the contamination of articles having different shapes, monitors are produced as a type having detectors attached on all sides (above, below, front, back, left and right) of the article to be measured, and a type having detectors attached on two surfaces, either above and below or left and right of the article to be measured.

(3) Safety measures

The moveable doors on a monitor are provided with a safety switch that, when touched, stops the gate operation so as to prevent the subject's fingers or arm from being pinched.

4.3 Features of the small article transfer monitor

The small article transfer monitor is installed near the entrance and exit access of the control room, and operates so as to measure efficiently the contamination of small articles such as writing instruments or tools that have been hand-carried into a radiation controlled area by a worker.

(1) Use of a beta + gamma-ray detector

A detector that combines scintillators for beta-ray and gamma-ray use is installed in the small article transfer monitor, enabling measurement of interior surface contamination (gamma-rays).

(2) Moveable upper detector

According to the shape of the subject article, the upper detector may be lowered to measure contamination at a closer distance and to implement highly efficient measurement regardless of the shape of the subject article.

(3) Storage of subject articles

Fig.5 Transportable small article monitor (type 2)



Table 2 Specifications of the article monitor

Item	Monitor name	Small article transfer monitor	Transportable small article monitor (type 1)	Transportable small article monitor (type 2)
Detector		$\beta+\gamma$ -ray detector	Same as on the left	Same as on the left
Detector positioning		Above, below, left, right, front, back of article to be measured	Above and below article to be measured	Left and right of article to be measured
Detection sensitivity (beta-rays) <Measurement conditions> BG Moving speed or measurement time Radiation source Measurement distance		0.4 Bq/cm ² 0.1 μ Sv/h 10 s ⁹⁰ Sr 100 mm $\times$ 100 mm 30 mm	0.4 Bq/cm ² 0.1 μ Sv/h 10 s ⁹⁰ Sr 100 mm $\times$ 100 mm 30 mm	0.4 Bq/cm ² 0.1 μ Sv/h 10 s ⁹⁰ Sr 100 mm $\times$ 100 mm 30 mm
Detection sensitivity (gamma-rays) <Measurement conditions> BG Moving speed or measurement time Radiation source Measurement distance		1.1 Bq/cm ² 0.1 μ Sv/h 10 s ⁶⁰ Co 100 mm $\times$ 100 mm 30 mm		
Size of article to be measured (W) $\times$ (D) $\times$ (H)		500 $\times$ 500 $\times$ 300 (mm)	420 $\times$ 300 $\times$ 120 (mm)	250 $\times$ 350 $\times$ 350 (mm)
Mass of article to be measured		20 kg	5 kg	5 kg
Example of article to be measured		○ Paper documents ○ Tools ○ Writing instruments ○ Small measuring instruments	○ Paper documents ○ Tools ○ Writing instruments	○ Helmets ○ Tools ○ Personal computers ○ Survey meters
Size (W) $\times$ (D) $\times$ (H)		1,000 $\times$ 1,900 $\times$ 1,600 (mm)	550 $\times$ 450 $\times$ 600 (mm)	460 $\times$ 600 $\times$ 600 (mm)
Mass		1,800 kg	50 kg	36 kg

After being measured, non-contaminated articles are transferred to a non-radiation controlled area conveyor. A stocker for storing these measured articles may be connected. The number of storage shelves in the stocker can be selected as, for example, eight shelves for 100 mm-tall measured articles or four shelves for 300 mm-tall measured articles.

4.4 Transportable small article monitor (type 1)

The transportable small article monitor is limited to use with notebooks and paper documents to be measured. Since a driving mechanism is not attached, the monitor is small and has a mass of approximately 50 kg. Moreover, since only a small installation space is needed, this monitor may be installed temporarily when many articles are being transferred.

The height at which the upper detector is attached can be selected from four levels: 40, 70, 100 and 130 mm, and can be set manually.

4.5 Transportable small article monitor (type 2)

This monitor is used to measure helmets and survey meters, which are relatively high (350 mm) compared to the articles measured with the abovementioned transportable small article monitor.

5. Laundry Monitors

5.1 Overview

Laundry monitors are used prior to washing to inspect efficiently whether clothes and the like used in a radiation controlled area are contaminated, and are also used after washing to inspect the surface of the

clothes. The articles measured are small, and include overalls, undergarments and other clothes, hats, gloves, socks, chin straps, etc. A small article pre-monitor or the like is used to measure the contamination of clothes prior to washing, and to separate articles having high levels of contamination. A clothing monitor or the like is used to inspect whether contamination remains on clothes that have been washed.

Typical examples of a small article monitor and a clothing monitor are presented below.

5.2 Features

- (1) Each monitor has an inspection sensitivity that adequately detects the legally prescribed contamination levels for articles that may be transferred outside of a radiation controlled area.
- (2) A clothes monitor having high processing capability can inspect approximately 250 pairs of overalls in one hour.
- (3) A low-noise, long-life plastic belt is used in the clothes conveyor part of a clothes monitor.
- (4) A static eliminator is provided to protect the workers from static electric shocks from charge that has accumulated on the clothes.
- (5) Various self-diagnostic functions are provided and the integrity of the measuring system is constantly being checked automatically.

5.3 Functions

- (1) Small article pre-monitor

This monitor measures contamination from small articles prior to washing. The subject articles that have been inputted into the monitor are transported

Fig.6 Small article pre-monitor



Table 3 Specifications of the small article pre-monitor

Item	Details
Type of radiation detected	Gamma rays
Detector	Plastic scintillation detector
Detection sensitivity	1.0 Bq/cm ² or less (Radiation source used : ⁶⁰ Co)
Processing capability	Approx. 250 pairs/h (undergarments)
Size (W) × (D) × (H)	Approx. 950 × 2,500 × 1,420 (mm) or less
Mass	Approx. 1,600 kg

by a belt conveyor and pass underneath a detector that inspects for contamination. Also, a sorting mechanism mounted at the rear of this monitor separates non-contaminated articles from contaminated articles. Furthermore, the operating method can be selected so as to return contaminated articles to the input side. The belt conveyor is made from a highly water-resistant material so that wet small articles can also be measured. Figure 6 shows the exterior appearance of a small article pre-monitor and Table 3 lists its specifications.

(2) Clothing monitor

This monitor measures contamination from clothing and small articles after washing. The subject articles that have been inputted into the monitor are squeezed by vertical conveyors, and are moved between vertically positioned detectors so as to inspect for contamination. A beta-ray detector having a wide range of sensitivity is used to enable measurement across the entire conveyor without any dead spots. Figure 7 shows the exterior appearance of a clothing monitor, and Table 4 lists its specifications.

6. Hand-foot-clothes Monitor

6.1 Overview

Hand-foot-clothes monitors are installed mainly in hospitals and in contamination inspection rooms at fa-

Fig.7 Clothing monitor



Table 4 Specifications of the clothing monitor

Item	Details
Type of radiation detected	Beta rays
Detector	Plastic scintillation detector
Detection sensitivity	1.0 Bq/cm ² or less (Radiation source used : ⁶⁰ Co) 0.37 Bq/cm ² or less (Radiation source used : ⁹⁰ Sr)
Processing capability	Approx. 250 pairs/h (overalls)
Size (W) × (D) × (H)	Approx. 1,000 × 2,500 × 1,350 (mm)
Mass	Approx. 3,000 kg

cilities which handle radioactive matter. The monitors detect surface contamination from radioactive matter adhered to workers' hands, feet, clothes and so on. The monitors detect beta-rays from among the radiation emitted by the radioactive matter, sound an alarm if a preset alarm level is exceeded, and display the locations of contamination on the workers' hands, feet and clothes.

Figure 8 shows the exterior appearance of a hand-foot-clothes monitor, and Table 5 lists its specifications.

6.2 Features

- (1) Automatically measures radiation contamination on hands and feet placed on the measuring location, and evaluates and displays the contamination locations.
- (2) Automatically measures the background (BG) level at regular intervals, subtracts the latest BG value, and minimizes the effect of fluctuations in the BG to perform accurate contamination measurement.
- (3) When contamination occurs, displays the contaminated location graphically on a color display, so that the measurement results can be verified easily.
- (4) The plastic scintillation detector used does not require replacement, unlike the case in which a

Fig.8 Hand-foot-clothes monitor



Table 5 Specifications of the hand-foot-clothes monitor

Item	Details
Type of radiation detected	Beta rays
Detector	Plastic scintillation detector
Detection sensitivity	1.0 Bq/cm ² or less (Radiation source used: ³⁶ Cl, ⁶⁰ Co) 0.2 Bq/cm ² or less (Radiation source used: U ₃ O ₈)
Measurement time	15 s (can be set within range of 1 to 999 s)
Size (W) × (D) × (H)	630 × 725 × 1,356 (mm) or less
Mass	Approx. 80 kg

limited-service-life GM tube is used.

- (5) The detector used to measure clothing contamination is made out of plastic and is lightweight so as not to burden the measuring worker.
- (6) The foot stand is low to enable easy placement of one's foot on the stand.
- (7) Wheels are utilized on the back surface side so

that the monitor can be moved by one person.

- (8) The monitor is separable into three parts so delivery and installation are easy.
- (9) Film to prevent contamination can be reeled up and replaced easily.
- (10) A printer may be used optionally.

6.3 Functions

The BG and contamination measurements are performed repeatedly. If the BG level has not yet been measured, the BG level is measured first, and after the completion of a preset number of BG measurements, the contamination is measured. Usually, the BG measurement is performed to update the stored value to the latest BG value.

There are two types of contamination measurements, hands and feet contamination measurement and clothing contamination measurement, each of which is performed independently. The hands and feet contamination measurement begins after full detection by the hand and foot detection sensor, and after completion of the measurement, the evaluation results are displayed on a screen. The clothing contamination measurement uses a probe-shaped detector attachment and measures while surveying the clothing surface. The results are displayed in real-time on a screen. The BG measurement is resumed after the contamination measurement is completed, and if the measurement results are abnormal, the background setting can be verified to determine whether there is contamination from the measurer or a monitor abnormality.

7. Postscript

Fuji Electric has been developing and delivering radiation contamination monitors to nuclear power plants throughout Japan in response to customer needs. In order to expand sales overseas, Fuji Electric intends to develop model varieties that support IEC standards.

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