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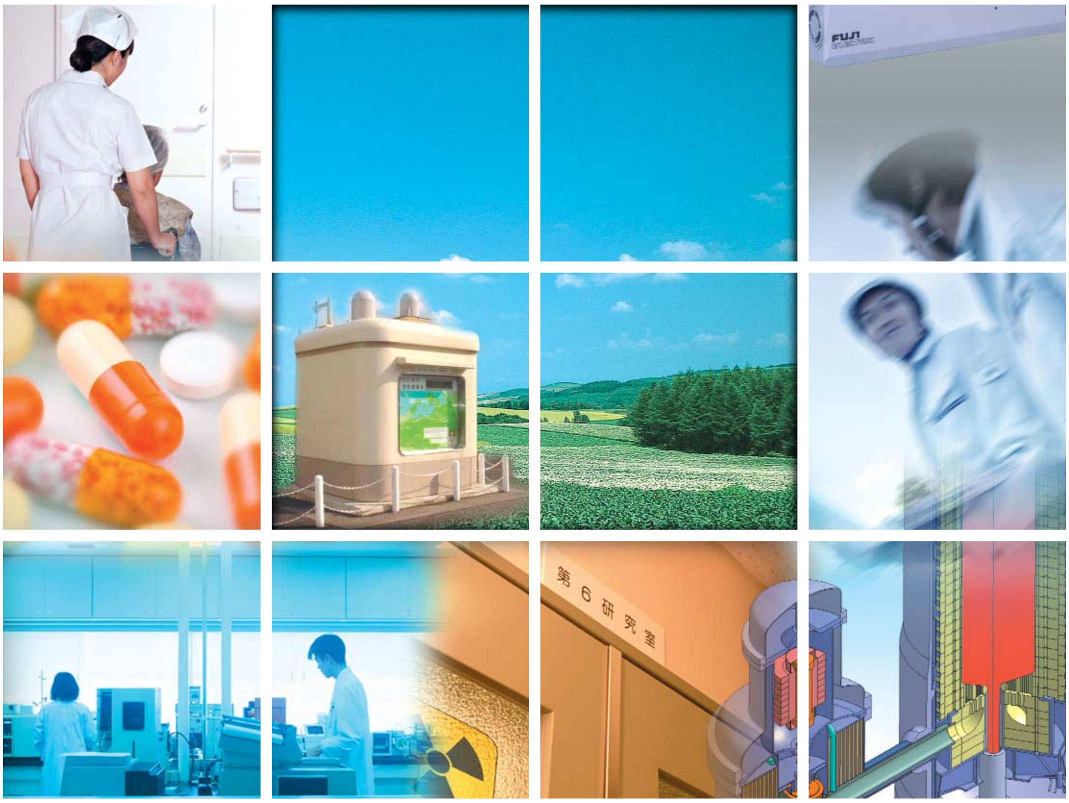
# FUJI ELECTRIC REVIEW

4

2004 VOL.50

## Radiation Monitoring Systems



Fuji Electric Group

e-Front runners

# Highly accurate and reliable equipment useful to our customers

Fuji Electric actively develops various types of essential radiation measuring instruments and computer systems to contribute to the safety control of nuclear power plants and other facilities that use radiation.

Detector that measures gamma-ray dose rates


Personal dosemeter that measures external radiation exposure

## Environmental radiation measurements

Detector that measures neutron dose rates

## Personal dose measurements


Whole body counter that measures internal contamination levels

Sample rack that tests for the emission of radioactive material

Body surface monitor that measures body surface contamination levels

# Fuji Electric's Radiation Control Systems

FUJI ELECTRIC
# REVIEW

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## Radiation Monitoring Systems

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**Cover photo:**

Because certain types of radiation, such as that used in X-ray machines for example, exhibit strong penetrating power and because the generated radioactive rays do not change even when subjected to heat or chemical treatments, radiation technology is widely used in the fields of medicine, pharmaceuticals and iron manufacturing, and at various research facilities. Although radioactive material is generated as a byproduct from nuclear facilities, as in the case of above-mentioned facilities that use radiation, appropriate controls are implemented to prevent adverse affects on humans.

In these fields, Fuji Electric is contributing positively to society by developing and supplying radiation monitoring devices and systems such as personal dosemeters to protect personal health and radiation monitors for ensuring environmental safety.

The cover photo illustrates the harmonious coexistence between facilities that use or require the control of radiation and their surrounding environment.

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# Current Trends in Radiation Monitoring Systems

**Etsuo Kono**

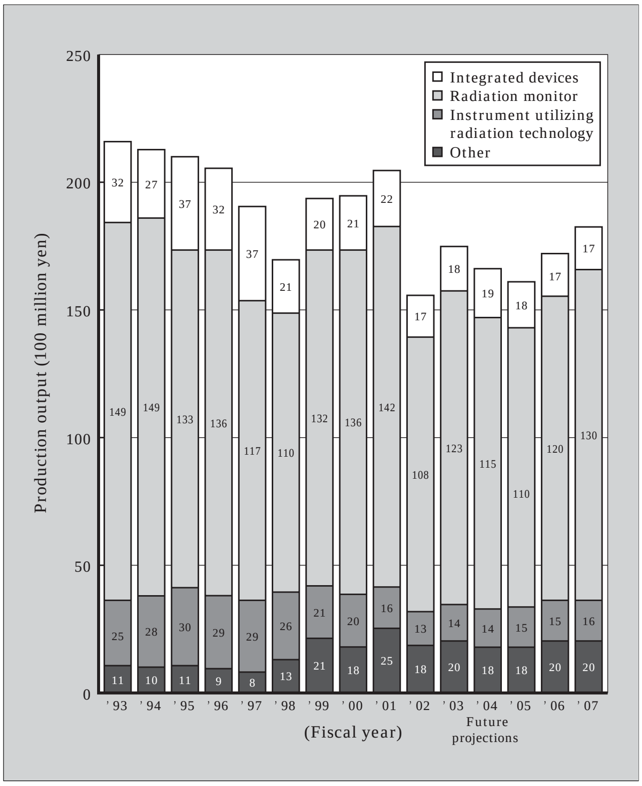
## 1. Introduction

During the more than 100 years since the discovery of X-rays in 1895 by the German scientist Roentgen, the use of radiation has been advanced in scientific, engineering and medical fields. The radiation measurement technology applied in industrial applications mainly utilizes the material penetration capability of radiation rays and is incorporated into production lines for iron and steel, paper, film, etc., where the technology is used in thickness gauges or cast-iron level gauges to measure the thickness or fluid level of an object rapidly, with high precision and without contact. In recent years, due to the overseas migration of iron/steel and chemical fiber production and the absence of an increase in production quantities, including the portion produced overseas, demand for measuring instruments that utilize radiation technology has continued on a downward trend.

On the other hand, radiation monitors are being shipped to facilities that use radioisotopes such as nuclear power plants, nuclear-related research organizations and universities, hospitals and pharmaceutical companies. When nuclear power facilities first began to be constructed, there was an increase in demand for radiation monitoring equipment, which gradually became the largest sector of the market for radiation equipment. Hospitals promoted the installation of diagnostic radiology equipment, and accompanying the use and control of medical isotopes that are administered to patients, radioactive wastewater treatment facilities and radiation monitoring equipment were also promoted.

Figure 1 shows the historical and future estimated production of radiation measuring instruments made by the Japan Electric Measuring Instruments Manufacturers' Association (JEMIMA). Demand for radiation monitors is largely dependent upon plans for the new construction of nuclear power plants, and the delay in construction planning effects the size of the market.

Fig.1 Production of radiation measuring instruments: historical output and future projections




## 2. Current Status of Radiation Monitoring Systems

Radiation monitors fall into the categories of environmental radiation monitoring, personal dose monitoring, surface contamination monitoring, radioactive material monitoring and area process monitoring.

Environmental radiation monitoring measures the spatial gamma-ray dose rate, the concentration of gaseous radioactive material, and the concentration of airborne radioactive material. Measurement of the spatial gamma-ray dose rate is implemented with a low range (background dose rate to 10 μSv/h range) monitor and a high range (10 μSv/h to 10 mSv/h range) monitor. NaI (Tl) scintillation detectors and spherical pressurized ionization chambers are used as radiation detectors. Radioisotope diagnostic radiology equipment is increasingly being used for in-hospital screenings, and monitor readings have a greater chance to fluctuate when, for example, a patient who has been internally administered a radioisotope approaches the environmental monitoring equipment or when a cart that transports radioactive elements passes nearby. Recently, low range monitors are being provided with the capability to measure spectral energy, and spatial gamma-ray equipment is increasingly being used to enable identification of the radiation source in cases when there is an unexpected change in the reading under normal measurement conditions. In combination with this function, energy characteristic compensation is being implemented with a digital method of energy load correction having good counting accuracy.

For the environmental dosimetry performed both on-site and off-site by fixed-point continuous gamma-ray monitoring, a transition is underway from passive dosemeters, such as a thermoluminescence dosemeter in which measuring-related processing such as the heating of an element is required, to electronic dosemeters capable of recording the history of dosage changes over time.

For personal dose monitoring, electronic dosemeters capable of measuring gamma-rays, beta-rays and neutrons are utilized in practical applications for measuring external exposure to radiation and are being used to record the doses. In particular, gamma-ray and beta-ray dosimetry will changeover to electronic dosemeters in the near future. Communication between the dosemeter and dose reader is gradually transitioning from infrared communication to wireless communication, and short-range communications technology is enabling data communication to be implemented with a dosemeter carried in a work clothes pocket or the like.

Surface contamination monitoring of a physical object is implemented by whole body surface monitors, article monitors, laundry monitors and the like. Plastic scintillation detectors for detecting beta-rays are used as radiation detectors because they are capable of measuring a large area within a short time interval.

For the dust monitors used in area process monitoring, a single radiation detector capable of detecting both beta-rays and alpha-rays, simultaneously and individually, is being used, making it possible to lessen the influence of radiation emitted from natural radioisotopes such as radon/thoron daughters. In facilities that handle nuclear fuel, large-area semiconductor detectors capable of discriminating alpha-ray energy are used, and dust monitors capable of measuring plutonium separation are being installed.

## 3. Technical Trends

Radiation monitoring equipment must be highly reliable. Technical development for the future is targeting smaller sizes, lighter weight, lower cost, longer useful life and even higher reliability.

Passive radiation detectors and finite-life radiation detectors such gas-filled counters and the like will be replaced with smaller-size and lighter weight semiconductor detectors. Because the silicon semiconductor material in a semiconductor element operates stably at room temperature and possess components similar to human body tissue, semiconductor elements are suitable for dosimetry and will continue to be used as the main element in future radiation detectors.

Construction of nuclear fuel reprocessing facilities and accelerator facilities is advancing and neutron dosimetry is crucially important at these facilities. Because at accelerator facilities, in particular, the neutron energy to be measured exceeds 10 MeV, development work is progressing for a new type of neutron detector, such as one in which material that boosts sensitivity of the neutron detector, which otherwise tends to decrease at high energy levels, is added to a conventional moderator.

## 4. Conclusion

Fuji Electric intends to develop commercial radiation monitoring equipment that uses mainly semiconductor radiation detectors and is optimally suited for various measurement conditions.

# Personal Dose Monitoring System

**Kei Aoyama**
**Osamu Ueda**
**Takeshi Kawamura**

## 1. Introduction

The level of radiation safety control in the nuclear power field and at facilities that utilize radiation has become stricter with the revision of the radiation protection regulations in April 2001 which incorporate the recommendations of the International Commission on Radiological Protection (ICRP Pub. 60) and the stipulation of a maximum exposure of 100 mSv/ 5 years in addition to the existing personal exposure dose limit of 50 mSv/year.

Since 2001, fluoroglass dosemeters and OSL (optically stimulated luminescence) dosemeters have replaced the conventional film badge as the personal dosemeters used in dose control. However, since the values measured by these dosemeters cannot be read directly, electronic dosemeters which permit the direct read-out of dose values and are equipped with an alarm function are recently being utilized for dose control.

Overseas, the usage of electronic personal dosemeters is also increasing, and an IEC standard has been established for electronic dosemeters capable of measuring gamma rays, beta rays and neutrons.

The Japanese domestic standard for electronic personal dosemeters achieved conformance with the IEC standard in 2002, and JIS Z 4312 "electronic personal dose (rate) meter for X-rays, gamma rays, beta rays and neutrons" was revised.

In 1980, Fuji Electric developed an alarm-equipped dosemeter that uses a semiconductor detector, and since then has continued to improve its dosemeter technology. Fuji Electric's personal dose control system, which increases the functionality of this electronic dosemeter and incorporates an area access control apparatus, has garnered an approximate 70 % share of the market among Japanese domestic nuclear power facilities.

## 2. System Overview

With Fuji Electric's personal dose monitoring system, a worker carries an electronic dosemeter when entering a controlled area for radiation such as a nuclear power plant, and the radiation dose received while the worker performs his or her task is measured. Upon leaving the controlled area, an area access control apparatus reads the dose data and a computer system manages the dose per worker and dose per task. Figure 1 shows an overview of this system. In the figure, the term "dosemeter" is used an abbreviation for "electronic dosemeter."

## 3. Electronic Dosemeter

An electronic dosemeter carried in a worker's pocket measures and displays in real time the amount of radiation received while the worker performs his or her task. This dosimeter is also equipped with a function that issues an alarm in cases where the exposure dosage exceeds a preset value. A silicon semiconductor detector that features a small size and low power consumption is used as the sensor.

Passive dosemeters such as film badges, which are characterized by a simple construction, and high durability and reliability, have previously been used widely as personal dosemeters. However, these passive dosemeters were disadvantageous because they did not permit the dose data to be read directly and because the process of obtaining monthly cumulative dose data was time consuming. Consequently, in nuclear power plants in Japan, concurrent with the usage of passive dosemeters, electronic dosemeters (equipped with an alarm function) were also used to monitor the dosage during work.

The development of electronic dosemeters has made progress in recent years, noise immunity and mechanical shock resistance have been enhanced, reliability improved, and the capability of measuring not only X-rays and gamma rays, but also beta rays and neutrons, has been realized. Additionally, the data communication capability provided with an electronic dosemeter enables easy connection to an external data processing system by means of infrared or wireless communications, enabling the configuration of a highly functional system for implementing rapid measurement archiving control, area access control, trend data measurement, and the like.

Fig.1 Overview of personal dose monitoring system

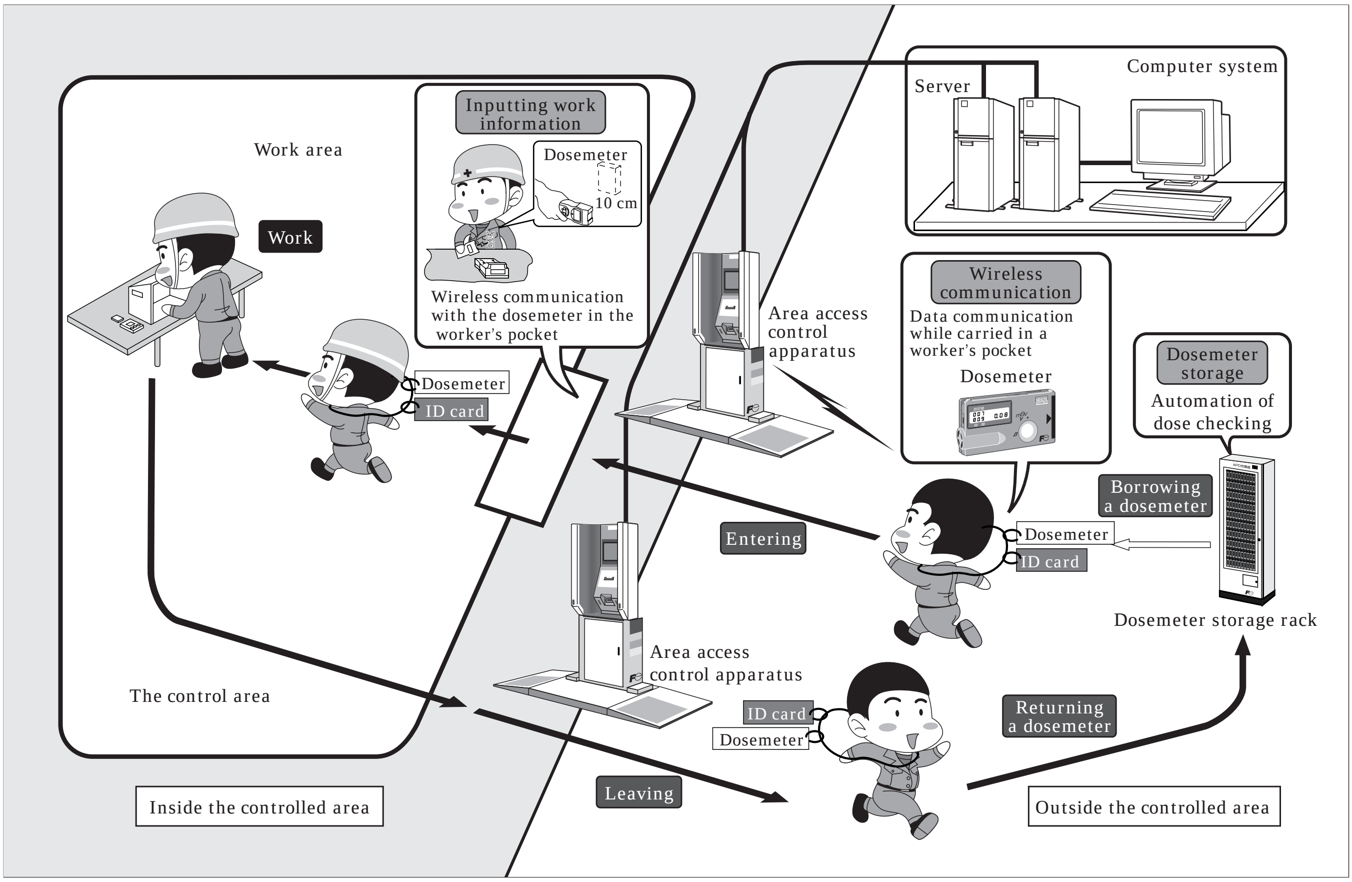
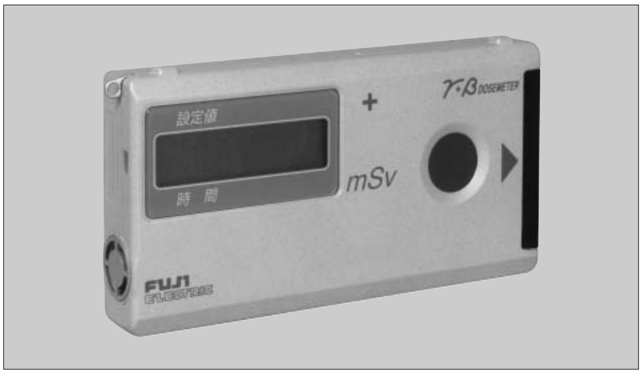



Fig.2 Gamma-beta dosemeter



Main features of electronic dosemeters are summarized below.

(1) Simultaneous measurement of multiple types of rays

X-rays, gamma rays, beta rays and neutrons can all be measured simultaneously (for the first time in the world).

(2) Good data reliability

Performance is equivalent to that of a conventional statutory dosemeter (passive dosemeter). Data reliability was confirmed by evaluating measurement data during concurrent use at actual nuclear power plants.

(3) Conformance with international standards

The International Electrotechnical Commission (IEC) standard (IEC 61526) and the Japanese domestic standard (JIS Z 4312) for electronic dosemeters are both satisfied.

Table 1 Specifications of the gamma-beta dosemeter

| | | |
|---|---|---|
| Dosemeter model | NRN64311 | |
| Detector | Semiconductor | |
| Radiation detected | Gamma (X) rays | Beta rays |
| Energy range | 50 keV to 6 MeV | 300 keV to 2.3 MeV |
| Energy response | ±20 %, $^{137}$Cs standard | ±30 %, $^{90}$Sr/ $^{90}$Y standard |
| Angular response | ±15 %, Up to 60° vertically and horizontally, $^{137}$Cs standard | ±30 %, Up to 60° vertically and horizontally, $^{90}$Sr / $^{90}$Y standard |
| Indication range | 0 to 999.99 mSv | 0 to 999.9 mSv |
| Accuracy of indication | ±10 %, 0.1 to 999.9 mSv | ±15 %, 0.1 to 999.9 mSv |
| Alarm | Sound level: 100 dB or greater, Display lamp: flashing LED (red) | |
| Communication method | Wireless (LF) and point contact | |
| Power supplies | NiCd rechargeable battery (providing power for 12 or more hours of continuous operation) | |
| Ambient temperature | 0 to 50°C | |
| Size | 110×57×17 (mm) | |
| Mass | 120 g | |

Fig.3 Gamma (X) ray energy response

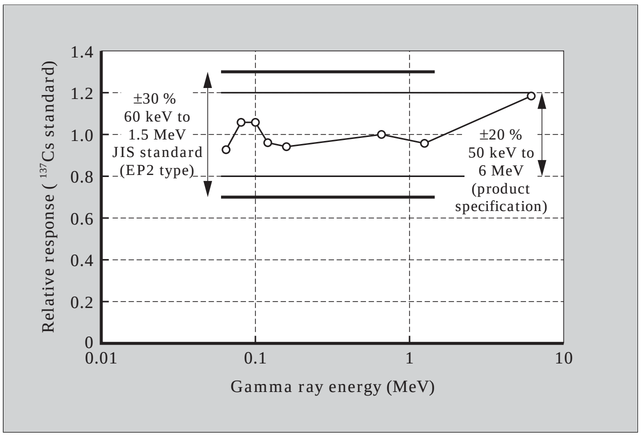
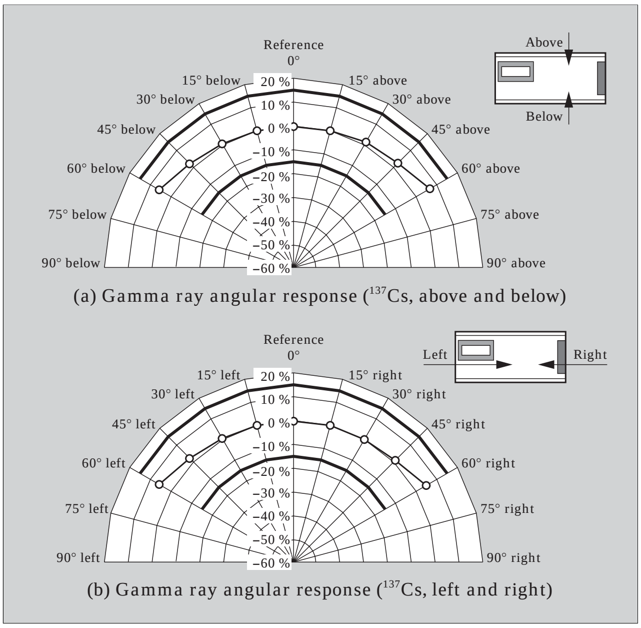



Fig.4 Gamma (X) ray angular response




(a) Gamma ray angular response ($^{137}$Cs, above and below)

(b) Gamma ray angular response ($^{137}$Cs, left and right)

Fig.5 Beta ray energy response

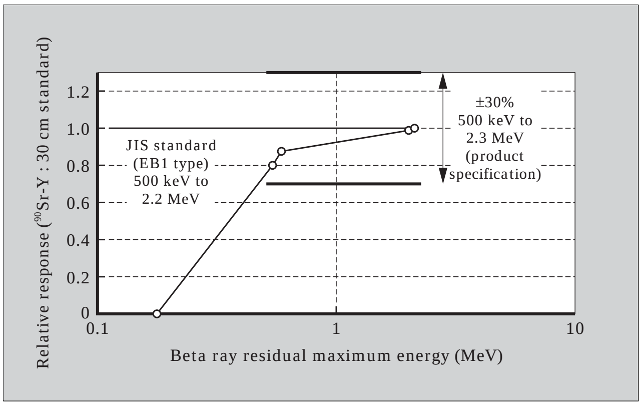
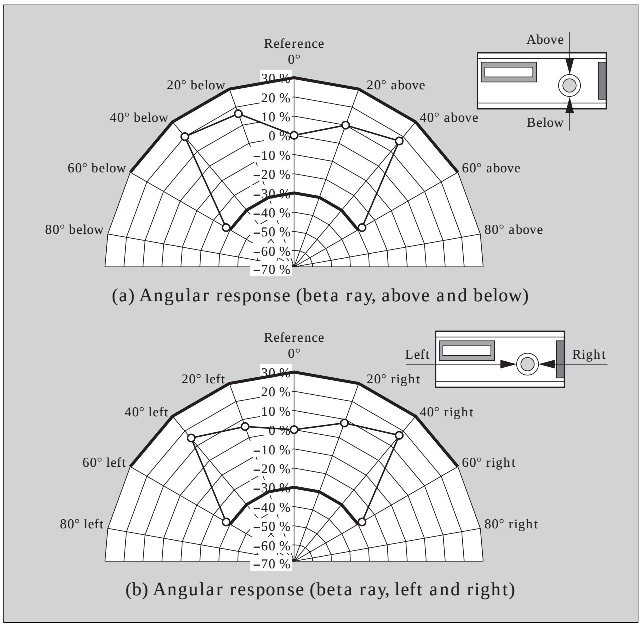



Fig.6 Beta ray angular response




(a) Angular response (beta ray, above and below)

(b) Angular response (beta ray, left and right)

(4) Wireless communication improves operability and shortens processing time

Data transfers between the electronic dosemeter and the area access control apparatus are implemented via wireless communication. Because data transfers can be implemented even while the dosemeter remains inside one's pocket, area access operability can be improved and processing time shortened.

Recently, some systems are being realized in which this wireless communication function is expanded to achieve remote wireless monitoring capability.

With the goals of streamlining dose control and reducing the burden on workers, control at many nuclear power plants in Japan is transition toward the use of only a single electronic dosemeter. The gamma (X) ray and beta ray dosemeter (hereafter referred to as the gamma-beta dosemeter) and the gamma (X) ray and neutron dosemeter (hereafter referred to as the gamma-neutron dosemeter) developed in response to these trends are described below.

### 3.1 Gamma-beta dosemeter

The gamma-beta dosemeter is equipped with two sensors, one for detecting gamma (X) rays and the other for detecting beta rays, enabling both types of radioactive rays to be counted simultaneously. The gamma-beta dosemeter is shown in Fig. 2 and its main specifications are listed in Table 1.

The gamma ray sensor is sealed in a ceramic package in order to improve the environmental immunity of its silicon sensor chip, and is provided with energy filters made of various types of metal to correct the energy response according to the direction of incidence (sensitive differs according to the gamma ray energy). Energy response is shown in Fig. 3 and angular responses are shown in Fig. 4.

Because beta rays have low penetrating power and can be stopped by a single aluminum substrate, the beta ray sensor is housed in a ceramic package made of resin film having a thickness of several tens of microns in the direction of incidence. Energy response is shown in Fig. 5.

In order to conform to the revised JIS Z 4312 standard, beta ray angular responses were improved as shown in Fig. 6. This improvement was achieved through widening the solid angle of beta ray incidence and enlarging the beta ray entrance window. The beta ray entrance window uses reinforcing material and is constructed so as not to be damaged under normal handling conditions.

### 3.2 Gamma-neutron dosemeter

The gamma-neutron dosemeter is equipped with two sensors, one for detecting gamma (X) rays and the other for detecting neutrons, enabling both types of radioactive rays to be counted simultaneously (Fig. 7). Main specifications of the gamma-neutron dosemeter are listed in Table 2.

Fig.7 Gamma-neutron dosemeter


Table 2 Specifications of the gamma-neutron dosemeter

| | | |
|---|---|---|
| Dosemeter model | NRY50312 | |
| Detector | Semiconductor | |
| Radiation detected | Gamma (X) rays | Neutrons |
| Energy range | 50 keV to 6 MeV | 0.025 keV to 15 MeV |
| Energy response | ±20 %, $^{137}$Cs standard | −50 to +150 %, (thermal neutron and $^{241}$Am-Be source: $^{252}$Cf standard |
| Angular response | ±15 %, Up to 60° vertically and horizontally, $^{137}$Cs standard | ±50 %, Up to 60° vertically and horizontally, $^{252}$Cf standard |
| Indication range | 0 to 999.99 mSv | 0 to 999.99 mSv |
| Accuracy of indication | ±10 %, 0.1 to 999.9 mSv | ±20 %, 0.3 to 999.9 mSv |
| Alarm | Sound level: 100 dB or greater, Display lamp: flashing LED (red) | |
| Communication method | Wireless (LF) and point contact | |
| Power supplies | NiCd rechargeable battery (providing power for 12 or more hours of continuous operation) | |
| Ambient temperature | 0 to 50°C | |
| Size | 110×57×17 (mm) | |
| Mass | 120 g | |

The gamma (X) ray sensor is similar to the gamma-beta dosemeter and its description is omitted here.

Because neutrons lack an ionization effect and cannot be detected directly, the neutron sensor reacts hydrogen or boron atoms with neutrons, and then detects the charged particles generated from that reaction. Moreover, due to the wide energy range (from thermal neutrons to 15 MeV) to be measured by the neutron sensor, two types of sensors are provided, a thermal neutron sensor for low energy use and a fast neutron sensor for high energy use. The silicon sensor chip of the thermal neutron sensor is formed with a boron thin film on its surface and is sealed within the sensor package.

$^{10}$B atoms contained in the boron film have a large cross-sectional area within which to react with low energy neutrons, and alpha rays and Li nuclei generated from this reaction are detected by the silicon sensor.

In the fast neutron sensor, polyethylene ($CH_2$) is

Fig.8 Neutron energy response

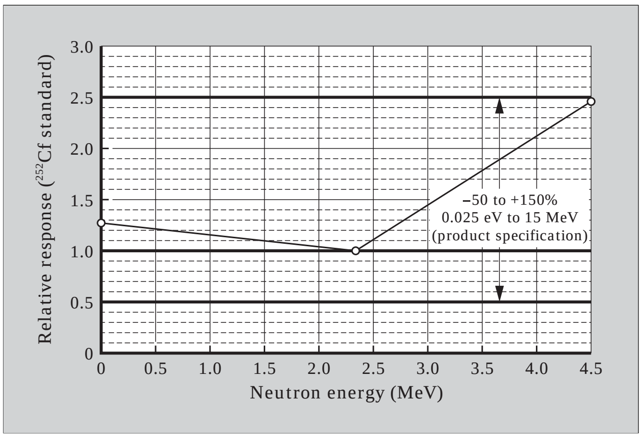
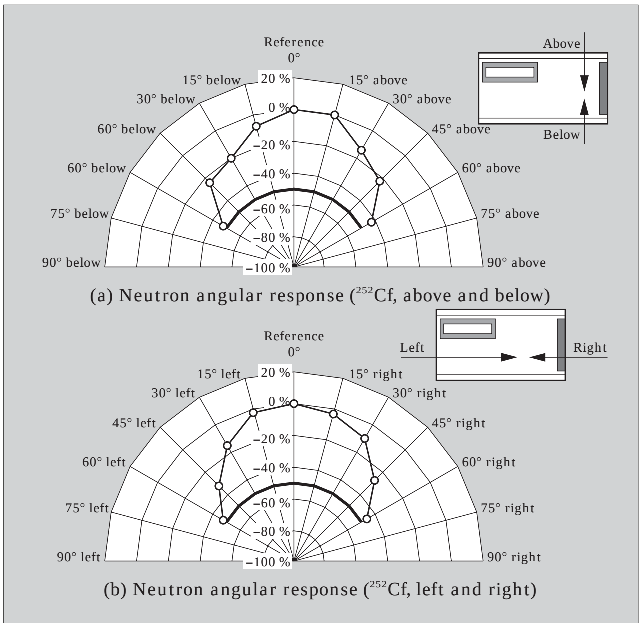



Fig.9 Neutron angular response




(a) Neutron angular response ($^{252}$Cf, above and below)

(b) Neutron angular response ($^{252}$Cf, left and right) disposed on the silicon sensor within the sensor package, and the silicon sensor detects recoil protons which are generated in reactions between neutrons and the hydrogen atoms contained in the polyethylene.

The neutron sensor is calibrated using a $^{252}Cf$ source (having an average energy of 2.3 MeV). In actual usage, it is important that a calibration constant, suitable for the radiation field of the work environment, be acquired in advance, and for this purpose a correction constant that allows a variable weighting of the count values of the thermal neutron sensor and fast neutron sensor is set internally, and the weighting is calculated according to the actual work environment in order to display the correct dose value.

Energy response is shown in Fig. 8 and angular responses are shown in Fig. 9.

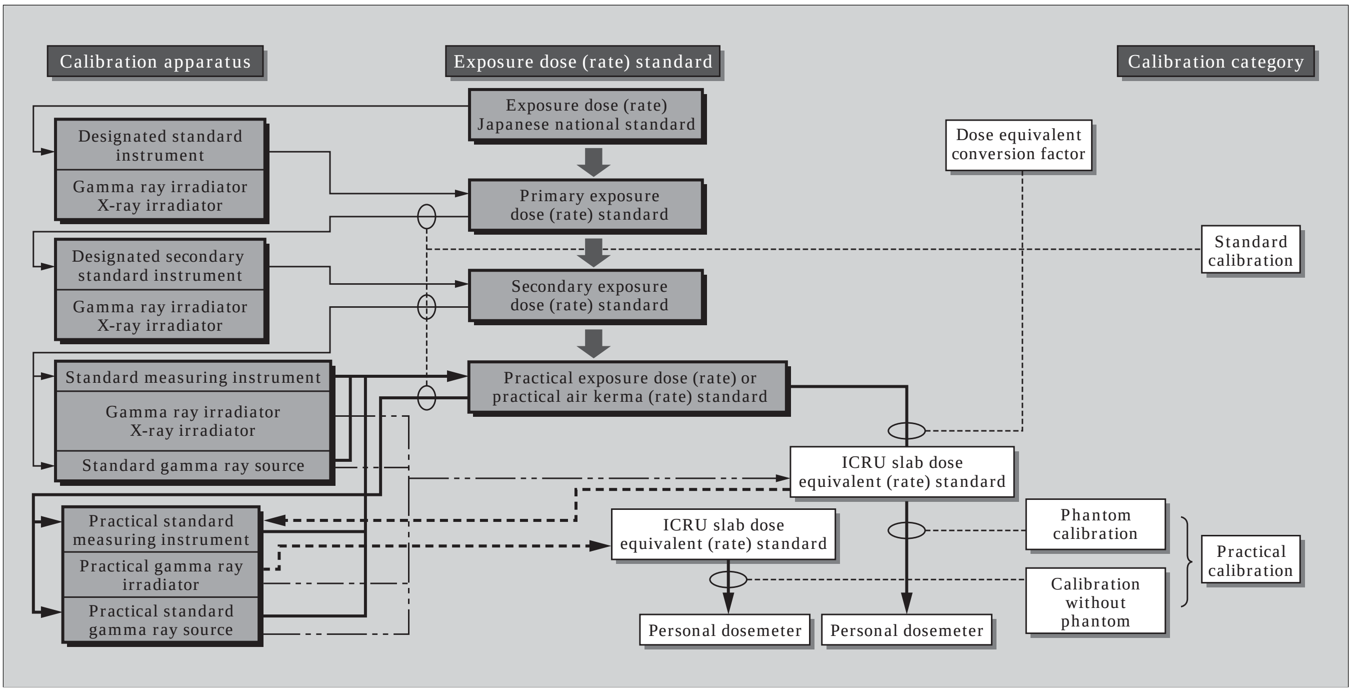
## 4. Area Access Control Apparatus

Installed at the border of the controlled area, the area access control apparatus automatically screens

Table 3 Area access control apparatuses

| Delivery to : | Company A | Company B | Company C | Company D |
|---|---|---|---|---|
| External appearance |  |  |  |  |
| Features | Integrated dosemeter storage rack.<br>Number of dosemeters : 150 units | Compact, lightweight, space-saving design | Large LED used for alarm indicator | Wireless communication with ID card (breast pocket) |
| Specifications | Dosemeters : NRY1, NRN1<br>Transit method : flapper gate<br>Transit time : approx. 15 s<br>Size : approx.<br>1,440 (H)×1,350 (W)×300 (D) (mm)<br>Mass : approx. 300 kg | Dosemeter : NRY4<br>Transit method : flapper gate<br>Transit time : approx. 7 to 8 s<br>Size : approx.<br>1,300 (H)×1,100 (W)×300 (D) (mm)<br>Mass : approx. 160 kg | Dosemeters : NRY5, NRN5<br>Transit method : pole gate<br>Transit time : approx. 7 to 8 s<br>Size : approx.<br>1,700 (H)×1,120 (W)×420 (D) (mm)<br>Mass : approx. 210 kg | Dosemeters : NRY6, NRN6<br>Transit method : no gate<br>Transit time : approx. 7 to 8 s<br>Size : approx.<br>1,600 (H)×780 (W)×400 (D) (mm)<br>Mass : approx. 200 kg |

Fig.10 Dosemeter calibration method



access to the controlled area, and possesses the following features.

(1) The exchange of data (such as dose data, dosemeter number, time length accessing to the controlled area, alarm value, etc.) between the electronic dosemeter and the apparatus is implemented via wireless communication.
(2) A reduction in transit time is achieved by simplifying input of the job number and by displaying a selectable list of the latest jobs on a screen when entering the area.
(3) The entire apparatus has a low profile form and high functionality.

Main components of the apparatus include an operation screen, a dosemeter communications unit, an ID card reader, a human presence sensor and a status indicator light. According to user needs, the apparatus may be integrated with an electronic dosemeter storage rack, and may be equipped with a gate and so on. Features and specifications of apparatuses that have been delivered to nuclear power related facilities are presented in Table 3. As can be seen from the

Fig.11 Gamma-beta calibration apparatus

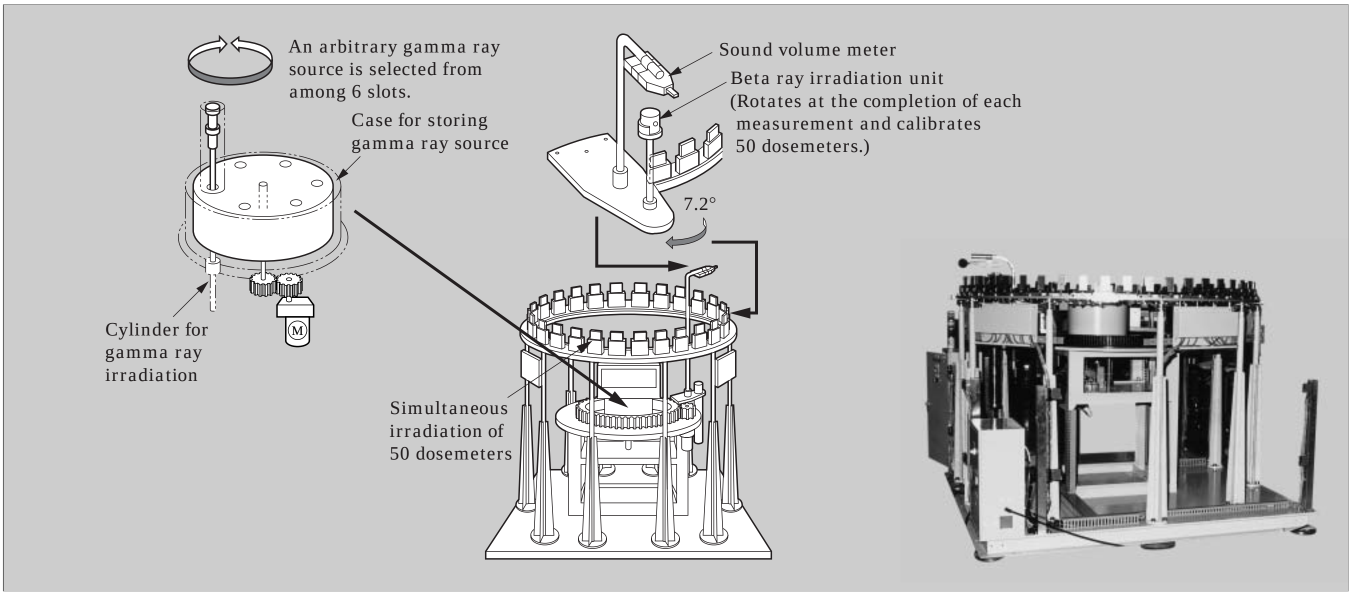
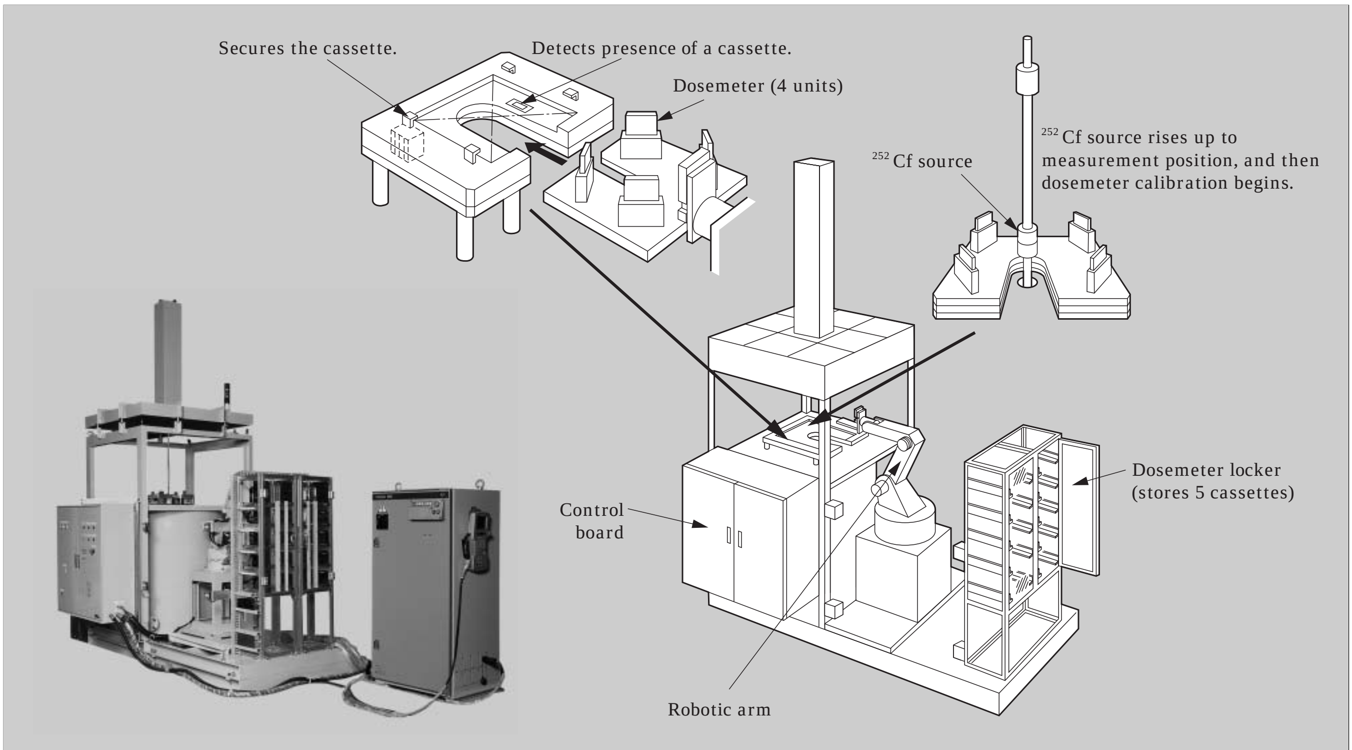



Fig.12 Neutron calibration apparatus



photographs of the apparatuses, the absence or presence of a gate, apparatus design, color and other features will distinguish each location where such an apparatus is installed. These products are made to correspond to a diverse array of user needs.

## 5. Calibration of Electronic Dosemeters

Electronic personal dosemeters must be calibrated in accordance with the method of JIS Z 4511, illustrated in Fig. 10. In accordance with the Japanese Measurement Law, an accredited laboratory calibrates an electronic personal dosemeter to which a phantom is attached, and then by using this calibrated dosemeter as a practical standard measurement instrument, other personal dosemeters of the same type can be calibrated by the substitution method without the use of a phantom. This method complies with the JIS standard for practical calibration and practical calibration by this method is thought to be possible not only with gamma rays, but also with beta rays and neutrons. Because the practical calibration of electronic dosemeters requires the calibration of many electronic dosemeters, Fuji Electric is developing practical calibration equipment such as a panoramic irradiator and a machine automated by means of a robotic arm. Figure 11 illustrates an example of a gamma ray and beta ray calibrating apparatus, and Fig. 12 illustrates an example of a neutron calibrating apparatus.

## 6. Conclusion

Fuji Electric's efforts in the field of personal dose monitoring systems have been presented with a focus on electronic personal dosemeters. So that these devices can be used in a wider range of facilities in the future, Fuji Electric intends to develop electronic dosemeters that are easier to use and have lower cost and greater accuracy in order to expand the scope of applications.

Finally, the authors wish to express their appreciation and gratitude to all those individuals at electric companies, nuclear power facilities and various research organizations who provided considerable guidance and assistance in the development and commercialization of the electronic personal dosemeter.

# Environmental Radiation Monitoring System

**Toshihiro Takagi**
**Osamu Kimura**
**Atsushi Minagoshi**

## 1. Introduction

In order to ascertain conditions near the perimeter of a supervised area at a nuclear power plant or other facility that uses radiation, environmental radiation monitoring systems operate to continuously measure the environmental gamma-ray dose rate.

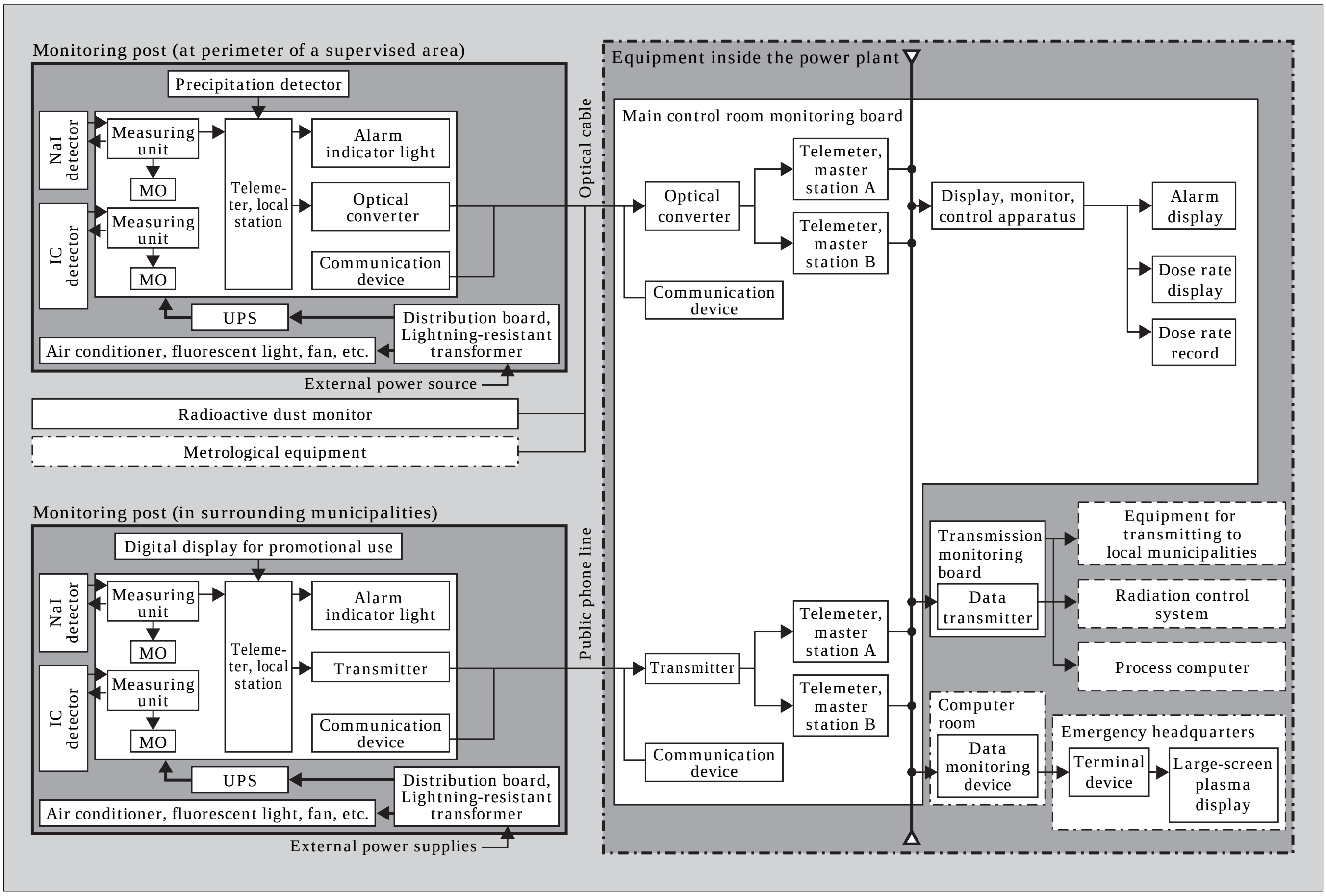
Moreover, in recent years, in order to provide the general public with a better understanding of the operation of nuclear power plants, measurement data is being reported publicly and sent to nuclear environmental monitoring facilities administered by local municipalities, and this dissemination of information has become an important service.

This paper describes Fuji Electric's latest environmental radiation monitoring system.

## 2. System Configuration

The system is configured from a monitoring post or meteorological equipment installed at the perimeter of a supervised area at a nuclear power plant, a telemeter that transmits measurement data to a main control room in the nuclear power plant, and a central data monitoring device that displays and controls the measurement data and alarms. Figure 1 shows an

Fig.1 System configuration (example)



example configuration of the system.

## 3. Monitoring Post

A monitoring post has a structure that houses a dose rate measuring device for continuous measurement of the environmental gamma-ray dose rate. Moreover, a structure equipped with both a dose rate measuring device and a radioactive dust monitor for measuring the concentration of airborne radioactive dust is known as a monitoring station. Monitoring posts and monitoring stations are generally installed at 3 to 9 sites near the perimeter of a supervised area of a nuclear power plant, and at 3 to 22 sites in the surrounding communities.

### 3.1 Environmental gamma-ray dose rate measuring device

In accordance with the guidelines for environmental radiation monitoring, the environmental gamma-ray dose rate is measured over a wide range, from the background (BG) level (several tens of nGy/h) to $10^8$ nGy/h. Measurement is therefore implemented with the combination of a NaI (Tl) scintillation detector (see Fig. 2) for measuring low dose rates and a spherical ionization chamber detector (see Fig. 3) for measuring high dose rates.

Fig.2 NaI (Tl) scintillation detector

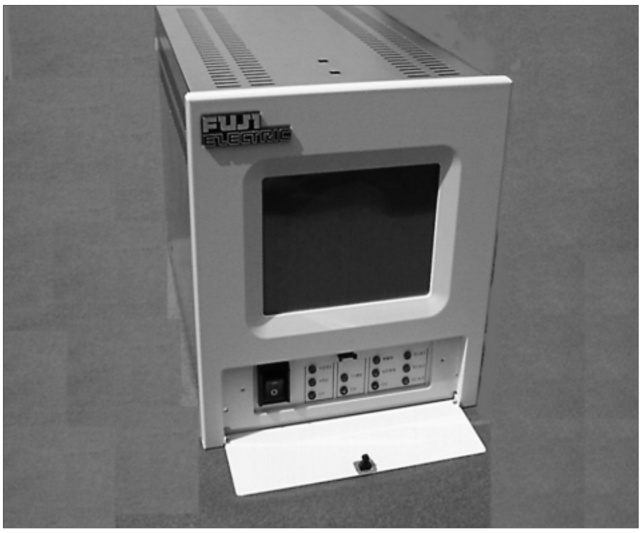
Fig.3 Spherical ionization chamber detector

Digitalization and small, high-density packaging technology enable the dose rate measuring device to be realized with a simple basic configuration that combines a detector unit and a measurement unit (having dimensions of approximately 21 (W) × 23 (H) × 30 (D) (cm)) (see Fig. 4) to achieve space savings and high reliability.

The detector unit of the low dose rate measurement system is equipped with an NaI (Tl) scintillator, a photomultiplier, an amplifier circuit, a high voltage circuit and a temperature compensating circuit, and is capable of outputting standardized pulse signals from the detector, without any temperature dependence. The measurement unit has two CPU boards, one board is for measurement use and contains an approximately 6-inch thin film transistor (TFT) color display and an energy compensation circuit, and the other board is for displaying, transmitting and storing the measured data. Because this measurement system uses an energy compensation method of spectral weighting with a digital weighting method (DWM), the conversion into a dose rate can be accomplished without decreasing the count precision, and a spectral data analysis function is able to identify radioisotopes from the gamma-ray energy information. Spectral data is also transmitted to the main control room at fixed intervals so that analysis can be performed offsite.

The detector unit of the high dose rate measurement system is equipped with an ionizing chamber, an amplifier circuit, a voltage frequency translation circuit and a high-voltage circuit. The measuring unit counts pulse signals sent from the detector unit and displays dose rate data. For this measurement system, some spherical ionization chamber detectors were also made from aluminum material, which has a smaller specific gravity than the conventional stainless steel material, enabling improved measurement accuracy of gamma-rays in the low energy range of less than

Fig.4 Measurement part of dose rate measuring device



400 keV.

The method of onsite recording of measurement data has changed from the conventional method of data recording with a data logger to a method in which measurement values are digitized and then stored on an optical disk. This method makes it possible to ascertain measurement value fluctuations, record the device status, and expand the data storage period, while also enabling data analysis to be performed simply with the use of a personal computer.

The high dose rate measurement system normally uses a spherical ionization chamber detector, but in order to provide the low dose rate measurement system with the capability to compensate measurements when trouble arises, a wide range NaI (Tl) scintillation detector capable of measuring the range from BG level to $10^8$ nGy/h was developed and the system configured. In the low range from BG level to $10^5$ nGy/h, this system measures and processes pulse signals from the detector. In the high range above $10^5$ nGy/h at which pulses cannot be measured, the system measures and processes an electric current signal that is proportional to the dose rate.

Main specifications of the low range measurement system, the high range measurement system and the wide range NaI measurement system are listed in Table 1.

### 3.2 Radioactive dust monitor

The radioactive dust monitor is a device that continuously measures the concentration of radioactive dust in the air. The detector unit measures beta-rays using a plastic scintillation detector, and integrates dust sampler and dust monitor that measures the concentration of dust collected in a paper filter. Also provided is a function that automatically samples radioactive iodine in a charcoal cartridge in cases where the environmental gamma-ray dose rate exceeds a preset alarm value.

The sampling pump uses an inverter to provide constant flow control and enable continuous sampling at the constant flow rate of 250 L/min even in cases when the flow rate fluctuates due to clogging of the paper filter or the like.

### 3.3 Monitoring station

The monitoring station (see Fig. 5) is assembled from precast autoclaved lightweight concrete (ALC) boards, the use of which shortens the time necessary for construction and reduces cost.

In order to publicly report the environmental radiation measurement data, monitoring stations in-

Table 1 Main specifications

| Item | Low-range measurement system | High-range measurement system | Wide-range NaI measurement system |
|---|---|---|---|
| Detector | NaI (Tl) scintillation detector | Spherical ionization chamber detector | NaI (Tl) scintillation detector (with energy filter) |
| Detector size | 2-inch diameter×2-inch height, etc. | Approx. 14.5 L | 2-inch diameter×2-inch height |
| Measurement range | BG level up to $10^5$ nGy/h | BG level up to $10^8$ nGy/h | BG level up to $10^8$ nGy/h |
| Reading error | Within ±10 % | Within ±10 % | Within ±20 % |
| Energy dependency | 50 keV to 3 MeV : within ±10 % | 50 to 400 keV : within ±15%<br>0.4 to 3 MeV : within ±10% | 50 to 100 keV : within ±20 %<br>50 keV to 3 MeV : within ±10 % |
| Directional dependency | Within ±10 % | Within ±3 % | Within ±10 % |
| Temperature characteristics (20°C standard) | Within ±3 % | Within ±5 % | Within ±5 % |

Fig.5 Appearance of monitoring station

Fig.6 Digital display

stalled in the communities surrounding a power plant are provided with a graphic panel that explains the role of the monitoring post and shows the locations of nearby monitoring posts, and a high-intensity light emitting diode (LED) display (see Fig. 6) that digitally displays the environmental gamma-ray dose rate.

Because the monitoring panel installed inside a monitoring station is a front maintenance-type panel, it can be installed with its rear surface in close proximity to a wall. By eliminating the rear maintenance space that had been necessary in the past, space-savings is achieved inside the monitoring station.

As measures against radiation fluctuation due to radon and thoron, an air blower is provided to ventilate the air in the detector unit and a heat exchanger ventilation apparatus is provided to ventilate the air inside the monitoring station so that there is no change in temperature.

Additionally, a mechanism for transporting detectors mounted on the roof into the monitoring station is provided. Because the spherical ionization chamber detector is particularly heavy, the use of a hoisting machine improves operability and safety.

## 4. Telemeter

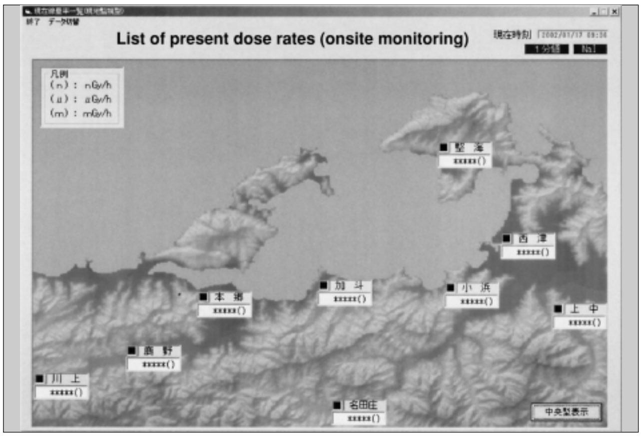
The 24-hour-per-day continuous transmission of data from a monitoring post to the monitoring board in the main control room is implemented via a transmission system in which a programmable controller (MICREX series), having a proven track record of high reliability, is configured as a telemeter. At monitoring posts near the perimeter of a supervised area at a power plant, optical fiber cable is used in the transmission path in order to prevent erroneous signals caused by the commingling of exogenous noise due to lightening or the like. At monitoring posts in the surrounding communities, public phone lines are used so that a transmission path can be secured easily.

The telemeter uses a broadcast transmission protocol that eliminates the need for the application software to acknowledge the transmission or reception of data. Measurement data from the monitoring post can be refreshed in 1-second cycles, and high-speed and highly reliable transmission is realized.

In consideration of the possible occurrence of a transmission path malfunction, the monitoring post telemeter is provided with the capability to store up to a maximum of 14 days of measurement data (values sampled every 30 seconds) in a memory card. After proper operation is restored, storage data can also be collected from the central data monitoring device or the like.

The main control room's telemeter (master station) that collects measurement data from each monitoring post is implemented as a dual-redundant system in order to avoid data dropout due to device malfunction.

Fig.7 Dose rate map display




This redundancy increases the system reliability.

Additionally, because the telemeter is provided with a computation function for converting a monitoring post's measurement data into the dose rate, and is able to perform what was previously a function of the computer system — the calculation of alarm setting values and conversion of measurement data into scientific values — the system can be simplified.

Furthermore, because the telemeter can expand control through PE link transmission (Fuji Electric's proprietary LAN), and is equipped with communication interfaces for serial communication, Ethernet*1 and the like, the transmission of measurement data even to nuclear power environmental monitoring facilities administered by local municipalities can be implemented easily.

## 5. Data Monitoring Device

The data monitoring device that displays data, monitors the system operation status, creates forms, etc. is centrally located, where measurement data from the monitoring posts is collected, stored and then aggregated. The data monitoring device is selectable as a Unix*2 server, FA computer, or the like according to the system size, and is designed for 24-hour continuous monitoring.

An example of the main functions is presented below for the case when a Unix server is used as the data monitoring device.

### 5.1 Screen display

(1) List of present dosage rates

Displays a list of the present values of the dose rate data and meteorological data

(2) Dose rate map display (see Fig. 7)

Displays present values of the dose rate data and meteorological data on a topographic map at the

*1 Ethernet: A registered trademark of Xerox Corp., USA

*2 UNIX: A registered trademark in USA and other countries licensed by X/Open Co. Ltd.

location of the monitoring post

(3) Dose rate trend display

Displays the dose rate data and precipitation data in a trend graph

By displaying the dose rate and precipitation data at the same time, the change in dose rate that accompanies precipitation can be assessed quickly. Also, the scale of the graph's vertical axis can be modified automatically.

(4) Alarm history display

Displays the incidence of and recovery from alarms generated by the system

(5) Alarm display panel

Displays the operating status of the system components in green (normal) or red (alarm generated) above the system configuration schema so that the operating status can be assessed quickly

(6) Spectral data display

Displays the spectral data per station or as a time series in 10-minute intervals

(7) Setup of operating constants

Sets the alarm values and the conversion constant for converting measurement data to scientific values

This setting screen manages security according to the security classifications of password administrator, setting modifier and setting visitor.

### 5.2 Form output

(1) Daily report

Prints the dose rate and other values (hourly values) of each monitoring post for a specified day

(2) Monthly report

Prints the dose rate (hourly values) and control standard values (average hourly values of the prior fiscal year $\pm 3\ \sigma$) of each monitoring post for a specified month

(3) Dose rate trend

Prints trends such as the dose rate for a specified period

### 5.3 Emergency headquarters data display function

The emergency headquarters of a nuclear power plant is provided with a large-screen plasma display and an emergency system capable of displaying various types of plant information so that the plant status can be assessed accurately in the case of an emergency. Environmental radiation data is also critically important data in an emergency.

This system is provided with a function for easily outputting environmental radiation data by connecting the data monitoring device to a LAN, so that it can be linked to this emergency system.

## 6. Conclusion

Extremely high reliability is required of an environmental radiation monitoring system because it must perform continuous 24-hour-per-day monitoring of the area surrounding a nuclear power plant (except during scheduled system maintenance), without any data dropout. Recently, measurement data from environmental radiation monitoring systems is being transmitted to nuclear environmental monitoring facilities administered by local municipalities and is also being displayed on each power plant's website.

Within this context, Fuji Electric intends to employ such comprehensive technologies as radiation measurement, data transmission, and computer system based control to their fullest extent and to develop systems with even higher reliability to meet customer needs.

The authors are extremely grateful for all the assistance received from employees of The Kansai Electric Power Co., Inc., the Ooi Power Station and other electric power companies and research institutes.

# Environmental Radiation Measuring Equipment

**Hironobu Kobayashi**
**Tsuyoshi Sakamaki**
**Kaoru Masui**

## 1. Introduction

Environmental radiation measuring equipment is commonly used at such facilities as nuclear power plants, research laboratories and hospitals for the purpose of measuring and controlling environmental radiation. Fuji Electric supplies various types of environmental radiation measuring equipment that support a variety of applications. In response to recent demands for environmental radiation measuring equipment that is smaller in size, has higher sensitivity and requires less labor, new products are being urgently developed to meet these needs.

This paper presents an overview of environmental radiation measuring equipment and introduces new models developed recently.

## 2. Environmental Radiation Measuring Equipment: Types and Uses

Fuji Electric's radiation measuring equipment can roughly be categorized as radiation control equipment, radiation monitoring equipment, and the detectors incorporated therein. Table 1 lists Fuji Electric's main products and their uses.

The survey meter is a representative example of radiation control equipment and is conveniently used to locate radiation leaks and search for surface contamination and radiation sources within a facility. Two types of recently developed radiation measuring equipment are introduced here, a low dose environmental dosemeter and a portable monitor post. Both of the radiation measuring devices have a simple configuration that can be connected to a PC for data processing, and they are portable for environmental dosimetry anywhere regardless of location. The low dose environmental dosemeter uses a semiconductor detector having approximately 100 times higher sensitivity than prior models (compared to prior models from Fuji Electric) and is capable of measuring low level doses. The portable monitor post uses a wide NaI (Tl) scintillation detector which is a single detector ranging from natural low dose rates to high dose rates.

Table 1 Main types of radiation measuring equipment

| Type | Product name | Use | Measured radiation | Measurement range |
|---|---|---|---|---|
| Radiation control equipment | Ionization chamber type survey meter | 1 cm dose equivalent, X instantaneous dose measurement | $\gamma$ (X) rays, $\beta$ rays | 1 $\mu$Sv/h to 30 mSv/h |
| | Scintillation type survey meter | Low level radiation monitoring and searching | $\alpha$ rays, $\beta$ rays, $\gamma$ rays | 1 to $10^4$ counts/s |
| | GM type survey meter | Measurement of leaking gamma doses and beta surface contamination | $\beta$ rays, $\gamma$ rays | 1 to $10^5$ counts/m |
| | Neutron REM counter | Measurement of leaking neutron doses | Neutrons | 0.1 $\mu$Sv/h to 9.999 mSv/h |
| | Personal dosemeter | Control of personal exposure at nuclear power facilities and the like | Neutrons, $\beta$ rays, $\gamma$ rays | 0.01 to 1,000 mSv |
| Radiation monitoring equipment | Portable monitoring post | Outdoor environmental dosimetry | $\gamma$ rays | 10 to $10^8$ nGy/h |
| | Low dose environmental dosemeter | Environmental dosimetry | $\gamma$ rays | 0.01 to 999,999.99 $\mu$Sv/h |
| Detectors, etc. | Semiconductor area monitor detector | Monitoring and measurement of air gamma doses at radiation facilities | $\gamma$ rays | 0.1 $\mu$Sv/h to 10 mSv/h |
| | Dust monitor semiconductor $\alpha$-ray and $\beta$-ray detector | Counting of alpha and beta rays contained in airborne dust | $\alpha$ rays, $\beta$ rays | 1 to $10^5$ counts/m |
| | Scintillation detector | Detector housed in a process monitor and the like | $\gamma$ rays | Varies according to use |
| | $\gamma$-ray ionization chamber detector | Monitoring and measurement of air gamma doses at radiation facilities | $\gamma$ rays | Varies according to use |
| | RI calibrator | Radioactivity measurement of medical radio isotopes used at hospitals | $\gamma$ rays | 0.1 MBq to 99.99 GBq |

## 3. Low Dose Environmental Dosemeter NSD Series

### 3.1 Overview

Fuji Electric Systems and the Tsuruga Power Station of The Japan Atomic Power Company began to collaboratively develop a series of low dose environmental dosemeters in 2000, and realized a successful commercial product in March 2004. This newly developed low dose environmental dosemeter NSD3 has approximately 100 times higher sensitivity than the ones in the past, which enables low level measurement as low as 0.01 μSv, compared to the previous models that could not measure doses below 1 μSv. An internal battery is installed in the dosemeter storage post for three-month continuous monitoring that can provide a longer trend than conventional one-week trend. This allows data collection for a three-month dose trend as same as thermoluminescence dosemeters (TLD), a longtime environmental monitoring means in the vicinity of nuclear power plants. In terms of easy data collection mechanism, our environmental dosemeters excel the conventional thermoluminescences, which saved labor costs, and then were implemented as a replacement with TLD. The system process flow is shown in Fig. 1.

### 3.2 Features and specifications

(1) Low dose environmental dosemeter

Features are listed below.

(i) The structure of the main unit is water/splash-proof that resists condensation and splash.

(ii) The high sensitivity of the detector enables background (BG) level variation to be monitored.

(iii) Three channels of energy information data can be stored.

(iv) Non-contact communication (infrared communication) is provided to communicate with its data collection terminal.

(v) Measurement data are stored in non-volatile memory so that the data can be read in an event of NSD3 malfunction.

Main specifications are listed in Table 2.

(2) Data collection terminal

The data collection terminal can store measurement results of the low dose environmental dosemeter and the features are listed below:

(i) Small size and light-weigh. Carried with the shoulder strap.

(ii) The terminal can collect and store three-month cumulative data from a maximum of 20 low dose environmental dosemeters NSD3.

(iii) Can maintain the data after battery expiration.

(3) Data processing system

Data stored in the data collection terminal are transferred through an RS-232C cable to a data processing unit (PC). The stored data can be displayed as a list of a 1-hour cumulative dose or as count values per energy level. If a large fluctuation in a trend data is observed, 1-minute trending feature is available for that data sampled to analyze in detail.

(4) Post for low dose environmental dosemeters

A battery is installed inside the dedicated dosemeter storage post for continuous low dose environmental dosimetry for three months or longer. The post has good ventilation to prevent an increase in internal temperature when exposed to direct sunlight, and water-resistant design that prevents rainwater infiltration. Even if installed in the post, the low dose environmental dosemeter NSD3 is able to communicate with the data collection terminal.

Fig.1 Process flow for a low dose environmental dosemeter system

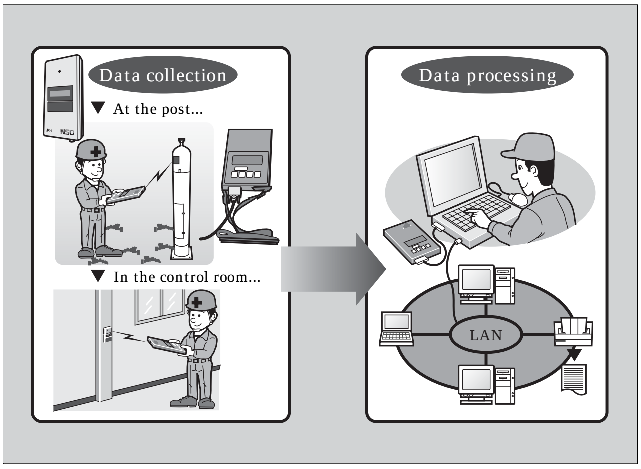



Table 2 Specifications of the low environmental dosemeter NSD3

| Item | Description |
|---|---|
| Radiation detected | γ (X) rays |
| Energy range | 50 keV to 6 MeV |
| Measurement dose | 0.01 to 999,999.99 μSv |
| Accuracy of reading | ±10 % ($^{137}$Cs) |
| Angular response | ±30 % (excluding dead zones) |
| Ambient temperature | −10 to +50°C |
| Size | 80 (W)×140 (D)×29 (H) mm |
| Mass | Approx. 300 g |

### 3.3 Characteristic data of the low dose environmental dosemeter

The dose rate linearity, at relative sensitivity ($^{137}$Cs reference), is within ±10 %. Also, angular responses (vertical and horizontal) for the low dose environmental dosemeter NSD3 when installed in the post are within ±30 % ($^{137}$Cs reference), (not including the dead zone due to the battery). Angular responses are shown in Fig. 2.

Fig.2 Angular response of low dose environmental dosemeter when installed in the post

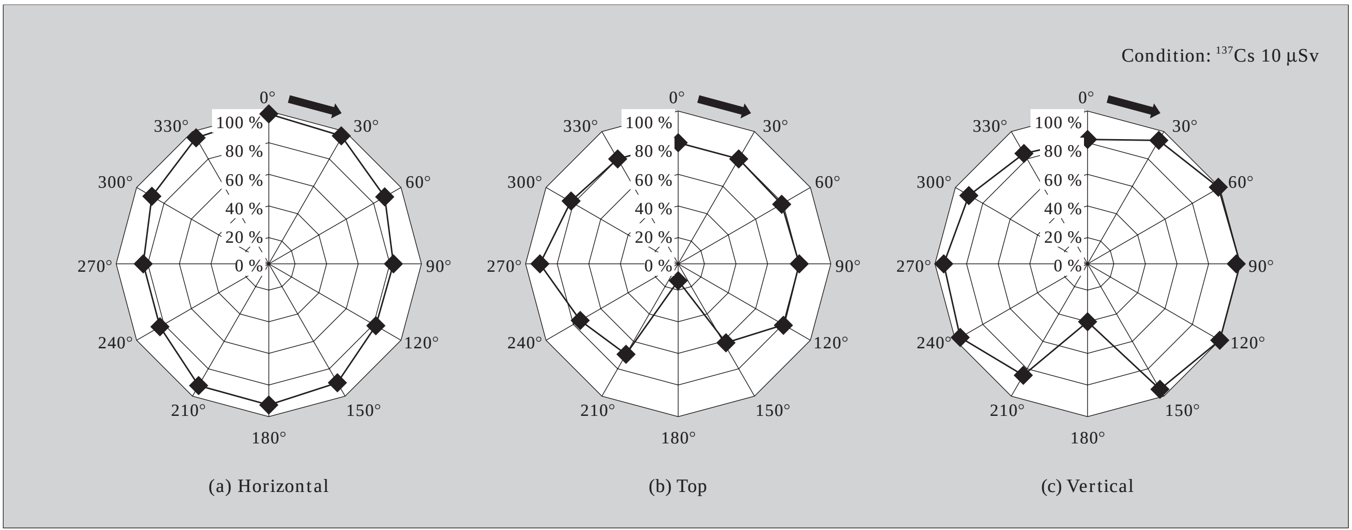



Fig.3 Comparison with monitoring post

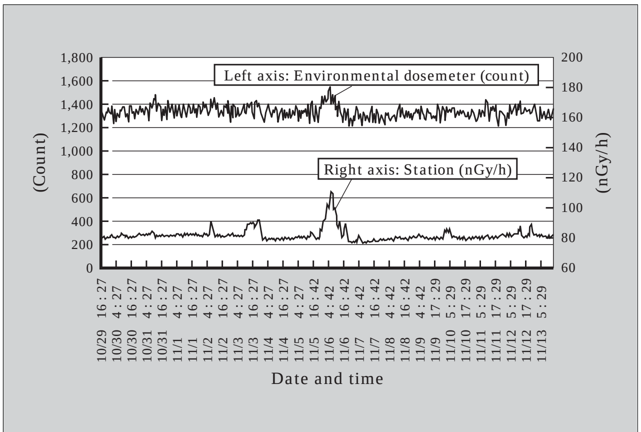



Fig.4 Appearance of the portable monitor post

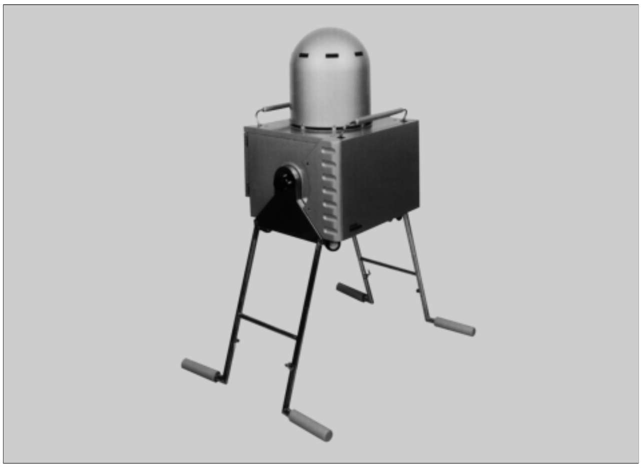
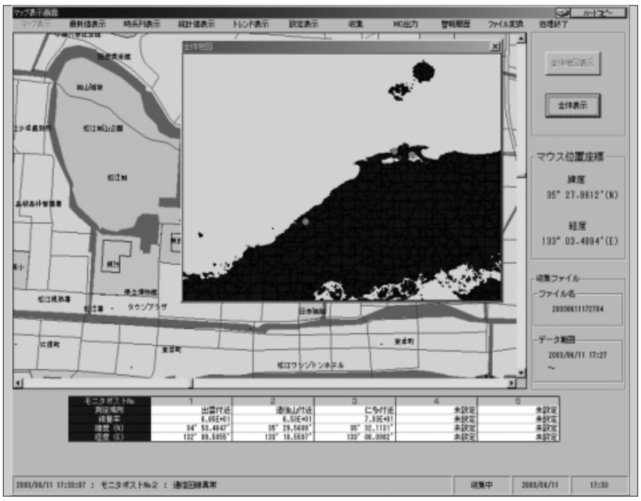


Fig.5 Example of environmental radiation dose rate map



### 3.4 Field comparison data

Comparison data for the low dose environmental dosemeter and a monitoring post (NaI detector) is shown in Fig. 3. Low dose environmental dosemeter readings (count values) follow fluctuations in monitoring post readings (nGy/h). This indicates that dosemeter is able to measure the background level doses with high precision.

## 4. Portable Monitor Post

### 4.1 Overview

The portable monitor post uses a wide NaI (Tl) scintillation detector and is able to measure air gamma dose rates over a wide range from the BG level to $10^8$ nGy/h. Featuring compact size and light weight, this portable monitor post can easily be transported and used for measurement. An internal global positioning system (GPS) and data transmission terminal enable transmission of dose rate and position information via a cell phone or other systems. For this reason, the portable monitor post is used as an environmental radiation monitoring post for emergency responses. Its external appearance is shown in Fig. 4.

An example of an environmental radiation dose rate map that uses the dose rate and location informa-

Table 3 Specifications of the portable monitor post

| Item | Specification |
|---|---|
| Dose rate measurement range | 10 to $10^8$ nGy/h<br>Low range region : 10 to $5\times10^5$ nGy/h<br>High range region : $3\times10^5$ to $10^8$ nGy/h |
| Dose rate measurement accuracy | ±10 % (reference : for $^{137}$Cs exposure) |
| Angular response | ±20 % (0 to ±90°) |
| Energy response | Low range area :<br>±20 % (from 50 keV to less than 100 keV)<br>±10 % (from 100 keV to 3 MeV)<br>High range area :<br>−50 to +25 % (from 50 keV to less than 100 keV)<br>−10 to +20 % (from 100 keV to less than 400 keV)<br>±10% (from 400 keV to 3 MeV) |
| Variation of indications | Coefficient of variation: 0.1 or less |
| Temperature characteristics | ±5 % (20°C reference) |

tion is shown in Fig. 5.

### 4.2 Features

The features are listed below:

(1) The portable monitor post may be used as a backup for non-moveable environmental radiation monitors.

(2) Compact size and lightweight structure of the portable monitor post makes it easy to transport and install.

(3) All-weather type for outdoor installation. Can be powered by an external battery when installed in where AC power is unavailable.

(4) Internal memory can store a 1-week measurement values (values measured every 1 minute).

(5) An energy response compensation circuit and a temperature compensation circuit are provided.

### 4.3 Specifications

The specifications are listed in Table 3.

### 4.4 Characteristics

So that a single detector can cover measurements in the range of 10 to $10^8$ nGy/h, the detector is used differently for the low and high range regions. For the low range region, it is used as a pulse-output type detector and for the high range region, it is used as a current-output type detector. Energy responses for each region are shown in Figs. 6 and 7.

Fig.6 Energy response in low range region

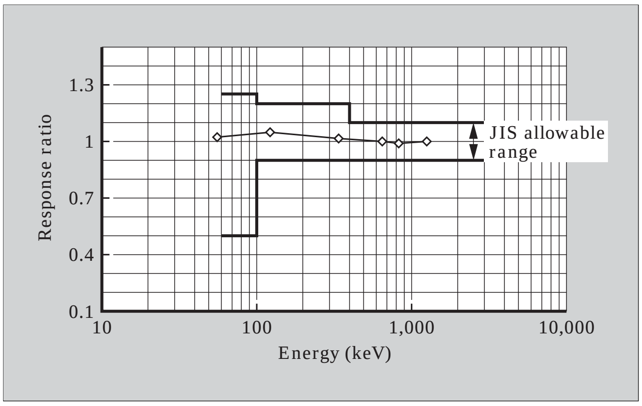
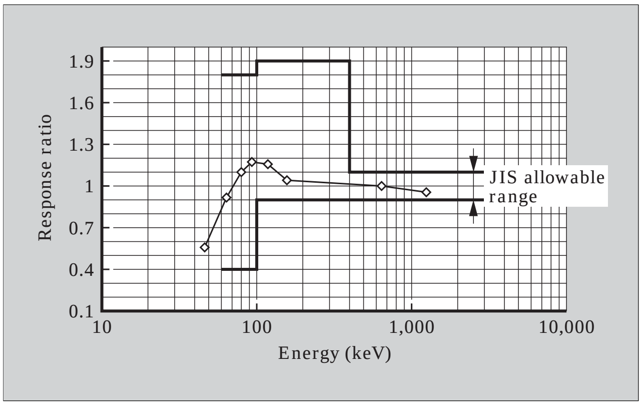



Fig.7 Energy response in high range region




## 5. Conclusion

The objectives of radiation control are to reduce exposures much further, to save labor and enhance functionality for dosimetry. Because the low dose environmental dosemeter and the portable monitor post achieve nearly the same performance as conventional large-sized measuring equipment and can store greater quantities of radiation data, future applications are expected. In the future, Fuji Electric intends to improve the performance in low energy and angular response.

In conclusion, the authors wish to express their gratitude to all members of the Environmental Safety Department of The Japan Atomic Power Company's Tsuruga Power Station from whom we received guidance and data useful in the development of the low dose environmental dosemeter.

# Radioactive Contamination Monitors

**Toru Hasegawa**
**Tadao Hashimoto**
**Manabu Hashimoto**

## 1. Introduction

In order to prevent the spread of radioactive contamination to areas outside a controlled area at a nuclear power plant, surface contamination inspection monitors are installed at the perimeter of the control area, and all articles moved from inside the control area to outside 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 surface contamination monitors that measure the surface contamination of articles ranging in size from large objects such as a scaffolding boards to small objects such as portable tools carried by workers, and laundry monitors that measure the surface contamination of clothes worn by workers inside the controlled area.

Other types of radioactive contamination monitors include a whole body counter that measures the internal exposure (internal contamination) levels of workers who work inside controlled areas, and a hand-foot-clothes monitor which is used mainly in hospitals and measures the surface contamination on hands, feet and clothes.

Fuji Electric uses large-area radiation detectors, signal processing units capable of high-speed arithmetic processing, mechanical units that establish the optimal conditions for measurement, and human-machine interfaces that use audible guidance and/or a large-screen color liquid crystal displays (LCDs) to make the high-sensitivity high-speed measurement of radioactive matter commercially practical, and has supplied these monitors to nuclear power plants throughout Japan. Additionally, these monitors are provided with a self-diagnosis function, which when connected to a data processing device apparatus, enables the central control of contamination inspection and measurement data.

This paper presents brief overviews and descriptions of the features of these monitors.

## 2. Body Surface Contamination Monitor

### 2.1 Overview

The body surface contamination monitor is installed at the exit of a controlled area and tests for the presence of contamination on the body surface of people exiting that controlled area. This apparatus is provided with detectors positioned to sense the entire surface of a person's body, and it capable of highly efficient contamination measurement within a short time. The height of the overhead detector adjusts automatically so that the head region can be measured with good sensitivity. This adjustable height function enables inspections for people of all heights, from short elementary school age children to tall adults, or more specifically from heights of 1,300 to 2,000 mm.

If the inspection finds no contamination, the worker is urged to go to the exit (non-controlled area), however if contamination is detected, the worker is prevented from exiting the controlled area. Figure 1 shows the appearance of this apparatus.

### 2.2 Characteristics

(1) Detection sensitivity

Beta-rays can be measured at a sensitivity of 0.4 Bq/cm$^2$. Conditions are listed in Table 1.

(2) Detector unit

A large-area plastic scintillation beta-ray detector is used.

(3) Optimum measurement time operating function

Measurement is usually performed within a fixed period of time (settable according to the type of operation), however, in order to minimize processing time according to the type of monitor, this function computes the optimal measurement time that satisfies the detection sensitivity, based upon the background (BG) count rate, and sets these parameters automatically to enable measurement within the shortest amount of time possible.

(4) Visitor function

The number of visitors has been increasing recently and this function allows the operation to be explained during measurement while the door is open.

(5) Miniaturization of the apparatus

Fig.1 Body surface contamination monitor

Table 1 Specifications of the body surface contamination monitor

| Item | Specification |
|---|---|
| Detector | Plastic scintillation detector |
| Number of detectors | 15 to 18 detectors |
| Detector sensitivity<br>Conditions :<br>BG<br>Measurement time<br>Radiation source<br>Distance | 0.4 Bq/cm$^2$<br><br>0.1 μSv/h<br>10 s<br>$U_3O_8$ 100×100 (mm)<br>Hands & feet : close contact<br>Head : 50 mm<br>Other : 100 mm |
| Processing capacity | Approx. 20 s |
| External dimensions | 860 (W)×1,000 (D)×2,250 (H) (mm) |
| Inner dimensions of measurement room | 500 (W)×700 (D)×2,000 (H) (mm) |
| Mass | 780 kg |

Two models are available, one with dimensions of 860 (W) × 1,200 (D) mm, and another model, developed for the purpose of increasing the number of machines within a limited space, and having dimensions of 800 (W) × 1,200 (D) mm. The inner dimensional width of the measurement room ranges from 400 to 500 mm for the former, and 400 to 440 mm for the latter.

(6) Easier maintainability

Maintenance can be performed in an open space in a non-controlled area.

(7) Guidance function

Operational guidance for measuring is provided to workers via an LCD and audible instructions. A model having a function to switch the screen display and spoken instructions to the English language is available to support use by non-Japanese speaking users.

(8) Connection to the data processing apparatus

The interface to the data processing apparatus is selectable as a LAN or as serial transmission. The data processing apparatus enables real-time monitoring of the operation status, display of measurement results, creation of forms and trend graphs, and the

Fig.2 Large article transfer monitor

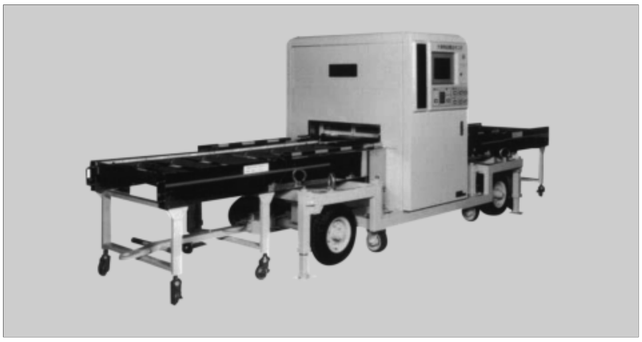


Fig.3 Small article transfer monitor

Fig.4 Transportable small article monitor (type 1)

Fig.5 Transportable small article monitor (type 2)

long-term storage of measurement data.

(9) Improved design

Because the structure was designed to feel spacious and open, the subject being measured will not endure a sense of oppression.

## 3. Article Surface Contamination Monitor

### 3.1 Overview

The article surface contamination monitor tests whether there is any contamination on the outer or inner surface of an article carried out from the controlled area. Variations of this monitor include a large object transfer monitor, a small article transfer monitor, and a personal handyphone system (PHS) transfer monitor. The appearance of each of these models is shown in Figs. 2 to 6.

### 3.2 Common features

(1) Detector sensitivity

Beta-rays can be measured at a sensitivity of 0.4 Bq/cm$^2$ and gamma-rays can be measured at a sensitivity of 1.1 Bq/cm$^2$. Conditions are listed in Table 2.

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

The monitor is fitted with a detector that integrates both a beta-ray and gamma-ray scintillator, and is able to measure the inner surface contamination (gamma-ray) of a pipe or the like.

(3) Moveable overhead detector

The overhead detector is lowered according to the profile of the article, and then measurement is performed. This enables the article to be measured at a close range and achieves highly efficient measurement regardless of the profile of the article.

(4) Safety measures

The moving parts of the apparatus, the conveyor and door, are provided with a bar switch or photoelectric sensor that halts their operation when touched in order to prevent accidental entangling of the operator's fingers or arms.

### 3.3 Large article transfer monitor

The large article transfer monitor is installed at the exit for carrying out large objects, and is used to measure efficiently the contamination of large and flat objects such as scaffolding boards and pipes that are removed in large quantities from the controlled area

Table 2 Monitor specifications

| Item / Monitor name | Large article transfer monitor | Small article transfer monitor | Transportable small article monitor (type 1) | Transportable small article monitor (type 2) | PHS transfer monitor |
|---|---|---|---|---|---|
| Detector | Plastic scintillation detector | Plastic scintillation detector | Plastic scintillation detector | Plastic scintillation detector | Plastic scintillation detector |
| Detector positioning | Top & bottom of object to be measured | Top & bottom, left & right,front & back of object to be measured | Top & bottom of object to be measured | Top & bottom of object to be measured | Top & bottom of object to be measured |
| Detector sensitivity (beta-ray)<br>Conditions :<br>BG<br>Moving speed or measurement time<br>Radiation source<br>Distance | 0.4 Bq/cm$^2$<br><br>0.1 μSv/h<br>20 mm/s<br>$U_3O_8$ 100×100 (mm)<br>30 mm | 0.4 Bq/cm$^2$<br><br>0.1 μSv/h<br>10 s<br>$U_3O_8$ 100×100 (mm)<br>30 mm | 0.4 Bq/cm$^2$<br><br>0.1 μSv/h<br>10 s<br>$U_3O_8$ 100×100 (mm)<br>30 mm | 0.4 Bq/cm$^2$<br><br>0.1 μSv/h<br>10 s<br>$U_3O_8$ 100×100 (mm)<br>30 mm | 0.4 Bq/cm$^2$<br><br>0.1 μSv/h<br>10 s<br>$U_3O_8$ 100×100 (mm)<br>30 mm |
| Detector sensitivity (gamma-ray)<br>Conditions :<br>BG<br>Moving speed or measurement time<br>Radiation source<br>Distance | 1.1 Bq/cm$^2$<br><br>0.1 μSv/h<br>20 mm/s<br>$^{60}$Co 100×100 (mm)<br>30 mm | 1.1 Bq/cm$^2$<br><br>0.1 μSv/h<br>10 s<br>$^{60}$Co 100×100 (mm)<br>30 mm | —— | —— | —— |
| Size of object to be measured | W1,500 mm<br>D 4,000 mm<br>H 300 mm | W 500 mm<br>D 500 mm<br>H 300 mm | W 420 mm<br>D 300 mm<br>H 270 mm | W 310 mm<br>D 220 mm<br>H 120 mm | W 160 mm<br>D 60 mm<br>H 30 mm |
| Mass of object to be measured | 200 kg | 20 kg | 5 kg | 5 kg | Lightweight object such as a PHS phone |
| Examples of objects to be measured | ○ Steel scaffolding<br>○ Scaffolding material<br>○ Scaffolding board<br>○ Pipe | ○ Documents<br>○ Tools<br>○ Writing instruments<br>○ Small measuring instruments | ○ Helmets<br>○ Tools<br>○ Writing instruments<br>○ Documents | ○ Documents<br>○ Tools<br>○ Writing instruments | ○ PHS |
| Size | W4,550 mm<br>D 2,110 mm<br>H 1,950 mm | W1,000 mm<br>D 1,900 mm<br>H 1,600 mm | W 560 mm<br>D 550 mm<br>H 750 mm | W 400 mm<br>D 315 mm<br>H 470 mm | W 260 mm<br>D 350 mm<br>H 270 mm |
| Mass | 4,000 kg | 1,800 kg | 60 kg | 18 kg | 15 kg |

Fig.6 PHS transfer monitor

during regularly scheduled inspections.

(1) Processing capacity

The detector unit has a width of 1,500 mm, enabling scaffolding boards, pipes and the like to be measured in bulk. For example, it is possible to measure more than 150 pipes (having a length of 4 m) within one hour.

(2) Measurement method

Long articles such as scaffolding boards and pipes can be placed directly on the conveyor and measured. However, small articles such as clamps and bolts are placed in a measuring dish and then measured.

(3) Creation of transfer forms

By registering the article and its quantity prior to measurement, the monitor's internal printer is able to printout a transfer form.

(4) Conveyor speed

Conveyor speed can automatically be set in the range of 10 to 100 mm/s, in increments of 10 mm/s. The automatic setting function calculates the optimal conveyor speed according to the BG level at the installation site and then sets the speed automatically.

(5) Moving the apparatus

The apparatus is fitted with a moveable dolly (with tires), and in the case of a battery-powered self-propelled dolly, the apparatus can be moved with just one person.

(6) Lateral movement

For locations having insufficient space for turning the apparatus, sideways-oriented wheels are provided in order to allow lateral movement so that the apparatus may be moved to any arbitrary position.

### 3.4 Small article transfer monitor

The small article transfer monitor is installed near the access control room, and is used to measure efficiently the contamination of small articles such as writing instruments and tools that were hand-carried by workers into the controlled area.

(1) Detector positioning

Two monitor models are manufactured to correspond to the shape of the article to be measured for contamination. One model is provided with detectors located at the top and bottom, front and back, and left and right positions, entirely surrounding the article to measured. The other model is provided with detectors positioned at the top and bottom (2 surfaces) of the article to be measured.

(2) Storage of measured articles

After being measured, the articles are transferred to a conveyor on the non-controlled area side, where a stocker that stores the measured articles may be attached. The number of articles storable by the stocker is selectable according to the operation as 8 tiers of 100-mm-tall articles, 4 tiers of 300-mm-tall articles, and so on.

### 3.5 Transportable small article monitor (type 1)

The transportable small article monitor developed for and delivered to customers in China is limited to the measurement of helmets, documents and tools, and weighs only approximately 60 kg since it is provided without a drive mechanism. With its small footprint, this monitor is also suitable for temporary use when large quantities of articles are being transported out of the controlled area.

The upper detector can be manually positioned at any of the 4 stages of 40, 120, 200 and 280 mm above the article loading surface.

### 3.6 Transportable small article monitor (type 2)

This monitor weighs only approximately 18 kg, which is even lighter in weight than the abovementioned transportable small article monitor, and can be moved easily by one worker wearing the shoulder belt accessory. Also, an optional battery unit can be used to power the monitor at locations where power could not otherwise be supplied.

### 3.7 PHS transfer monitor

This monitor is specialized for the measurement of small articles such as PHS phones. With compact external dimensions of 260 × 350 × 270 (mm), this monitor can be installed in the vacant space above a counter.

## 4. Laundry Monitor

### 4.1 Overview

The laundry monitor is used to detect efficiently the surface contamination of clothing worn inside the controlled area, before or after washing. The objects to be measured are clothing such as overalls and undergarments, small articles such as hats, gloves and socks, and molded articles such as helmets and shoes.

A front monitor inspects unwashed clothes and the like, and screens out highly contaminated articles not suitable for washing. The small article front monitor is an example of this type of monitor. A rear monitor inspects washed clothes and the like for residual contamination, and the clothes monitor is one example of this type of monitor. A folding machine and a sorting machine automatically separate contaminated articles from normal articles. While separating the articles, the folding machine automatically folds the normal uncontaminated clothing. By connecting these machines to contamination monitors, labor savings and higher throughput can be realized. This paper will introduce the front monitor, small article front monitor and clothes monitor.

### 4.2 Features

(1) Monitors for clothing, small articles and molded articles, and the front monitor, are completely compatible with the inspection goal and with the article to be measured.
(2) The clothes monitor and small article front monitor have detection sensitivities capable of detecting 1/10 the legally prescribed reference value for articles removed from controlled areas.
(3) The high-capacity clothes monitor is capable of processing about 250 pairs of overalls within one hour.
(4) The conveyor unit of the clothes monitor recently has been using a resinous round belt having low cost, low noise and long life, instead of the conventional wire net conveyor.
(5) A static eliminator is provided to protect workers from static electric shocks.
(6) The measurement system has an extensive self-diagnosis function that enables easy confirmation of the well-being of the system.

### 4.3 Function

(1) Clothes monitor

This monitor measures clothes and small articles after they have been washed. When used in combination with the folding machine, this monitor handles clothes exclusively. The article to be measured is placed into the monitor, picked up by a vertical conveyor and moved between upper and lower detectors, to inspect it for contamination. The large-area beta-ray detector that is provided has no dead zones over the entire width of the conveyor, and this monitor achieves smaller size and lighter weight than previous models. If a folding machine is connected, normal articles and contaminated articles are separated automatically and the normal articles are folded. The external appearance of the clothes monitor is shown in Fig. 7 and its specifications listed in Table 3.

(2) Small article front monitor

This monitor measures small articles exclusively, before they have been washed. The measurement method is the same as that of the clothes monitor. A sorting machine provided at the rear of this unit separates normal articles from contaminated articles. However, due to a different method of operation, this monitor also supports the return of contaminated articles to the insertion site. Moreover, the belt used is highly durable and compatible with wet articles. The external appearance of the small article front monitor is shown in Fig. 8 and its specifications listed in Table 4.

(3) Front monitor

This monitor inspects the contamination of unwashed clothes and the like that have been placed in a stainless steel wire-mesh bucket (well area). When placed into the bucket, measurement starts automatically and the result is displayed after a fixed-time measurement has been performed. An alarm is issued if the articles are judged to be contaminated. To simplify decontamination, the bucket has been designed to be easily detachable. The entire monitor is smaller and requires less installation space than prior models. The external appearance of the front monitor is shown in Fig. 9 and its specifications listed in Table 5.

Fig.7 Clothing monitor, folding machine


Table 3 Specifications of the clothing monitor

| Item | Description |
|---|---|
| Radiation detected | Beta-rays |
| Detector | Plastic scintillation detector |
| Detection sensitivity | 1.0 Bq/cm$^2$ or less (radiation source : $^{60}$Co)<br>0.37 Bq/cm$^2$ or less (radiation source : $U_3O_8$) |
| Processing capability | Approx. 250 (or more) articles of clothes per hour |
| Size | Approx. 1,350 (H)×1,000 (W)×2,500 (D) (mm), not including projections |
| Mass | Approx. 3,000 kg |

## 5. Whole Body Counter

### 5.1 Overview

In order to determine whether radiation workers who work inside a controlled area have internal radioactive contamination and to ascertain the internal radioactive mass necessary for qualitative and quantitative analyses and for computation of the committed effective dose equivalent (internal exposure

Fig.8 Small article front monitor

Table 4 Specifications of the small article front monitor

| Item | Description |
|---|---|
| Radiation detected | Gamma-rays |
| Detector | Plastic scintillation detector |
| Detection sensitivity | 1.0 Bq/cm$^2$ or less (moving speed : 100 mm/s, radiation source: $^{60}$Co) |
| Processing capability | Approx. 250 (or more) undergarments per hour |
| Size | Approx. 1,420 (H)×950 (W)×2,500 (D) (mm) |
| Mass | Approx. 1,600 kg |

Fig.9 Front monitor

Table 5 Specifications of the front monitor

| Item | Description |
|---|---|
| Radiation detected | Gamma-rays |
| Detector | NaI (Tl) scintillation detector |
| Detection sensitivity | 37 Bq/cm$^2$ or less (radiation source: $^{60}$Co) |
| Processing capability | 300 or more kg/h (evaluated at 5 kg per collection bag, and process time of 60 s/cycle) |
| Size | Approx. 1,000 (H)×800 (W)×950 (D) (mm), not including projections |
| Mass | Approx. 2,500 kg |

Table 6 Basic specifications of the whole body counter for screening measurement

| | |
|---|---|
| Detector | Plastic scintillation detector or NaI scintillation detector |
| Shielding method | Shadow shield method (bed type) |
| Measurement time | 30 s to 20 min |
| Energy range | 0.1 to 2.0 MeV |
| BG value | Approx. 2,500 to 4,000 m$^{-1}$ (30-minute measurement) |
| Detector sensitivity | Approx. 150 to 250 Bq ($^{137}$Cs) Approx. 50 to 100 Bq ($^{60}$Co) |

Table 7 Basic specifications of the whole body counter for precise measurement

| | |
|---|---|
| Detector | High-purity germanium detector or NaI scintillation detector |
| Shielding method | Shadow shield method (bed type) |
| Measurement time | Approx. 10 min |
| BG value | Approx. 2,500 to 4,000 m$^{-1}$ (0.1 to 2.0 MeV: 30-minute measurement) |
| Detector sensitivity | Approx. 150 to 250 Bq ($^{137}$Cs) Approx. 60 to 90 Bq ($^{60}$Co) |

dose equivalent), a whole body counter (WBC) externally measures gamma-rays emitted from radioactive matter within the human body.

### 5.2 Features

(1) Measurement system that suits the objective

The measurement to determine the presence of contamination in the body is known as screening, and the measurement implemented after internal contamination has been detected is known as precise measurement. Accordingly, Fuji Electric manufacturers both a WBC for screening use and a WBC for precise measurement use.

Specifications of bed-types of the WBC for screening use and the WBC for precise measurement are listed in Tables 6 and 7, respectively.

(2) Types

WBCs are categorized as either bed-type or chair-type, according to the position of the subject being measured. With the bed-type WBC, the subject lies on a bed and measurement is implemented by moving the bed inside a shield. With the chair-type WBC, the subject sits on a chair inside an open-type shield and is measured. Additionally, in some cases a sealed-type shield that encloses the entire room with 200-mm-thick steel plates is used. At the entrance/exit, either a door or a maze configuration is employed. WBCs are characterized by low BG and the capability for precise measurement.

The external appearance of these WBCs are shown in Figs. 10 and 11.

(3) Concern for the subject being measured

The subject must be tested while inside a shielded

Fig.10 Bed-type whole body counter

Fig.11 Chair-type whole body counter


body, but guidance for the measurement is provided via audible and displayed instructions so that the subject does not become confused. Additionally, the shield is designed to be soft and to have smooth contours so that it appears less intimidating.

Also, in some cases the showing of a movie during measurement lessens the stress endured by the subject. Fuji Electric is continuing to improve comfort during testing.

(4) Easing the burden on the operator

Processing, from the provision of measurement guidance until implementation of the measurement, can be automated and when measurement is complete, the measurement data can be transmitted to an upper level computer. This data is used in the WBC inspection performed when entering a controlled area.

The measurement results can also be stored in a data processing apparatus and verified on the display screen of that apparatus. The data processing apparatus runs on a Windows*[1] operating system to improve visibility and simplify the process of verifying the measurement results.

If the operator has an ID card, measurement can be performed even during the nighttime hours or on holidays. This is a large factor in easing the burden on the operator.

(5) Support of diversifying data control methods

The data processing apparatus is provided with an end user computing (EUC) function, and in accordance with the control, necessary data can be extracted and displayed on a screen.

(6) Support of unmanned operation

In response to requests for laborsavings and to support unmanned operation, a network is utilized to share input data effectively with an upper level computer, and WBC inspection scheduling, the transmission of relevant measurement data among related departments and companies and the like is systematized. A system capable of unmanned measurement for regular users is also pursued.

## 6. Hand-foot-clothes Monitor

### 6.1 Overview

The hand-foot-clothes monitor is installed in contamination inspection rooms at facilities that handle radioactive matter such as research laboratories, hospitals, and nuclear power plants, and detects the surface contamination of radioactive matter that has adhered to workers' hands, feet, clothes and the like. The monitor detects beta-rays emitted from radioactive matter, and if the detected value exceeds a preset alarm level, the monitor sounds an alarm and displays the location of contamination on hands, feet or clothes.

The external appearance of the hand-foot-clothes monitor is shown in Fig. 12 and its specifications listed in Table 8.

### 6.2 Features

(1) Simply placing a hand or foot at the measurement position will cause measurement to begin, the contamination evaluated and the results displayed automatically.
(2) The BG value is automatically measured at regular intervals, and a subtraction calculation is performed according to the latest BG value. By reducing the effect of BG fluctuation, contamination can be measured with greater accuracy.
(3) According the latest BG value, the detectable limit is computed and the measurement time is automatically adjusted so that contamination can be measured within a short amount of time.
(4) When contamination is detected, a color display graphically shows the location of the contamination so that measurement results can be easily verified.
(5) A plastic scintillation detector is used and, unlike a finite-life GM tube, does not require replace-

*1 Windows: A registered trademark of US-based Microsoft Corp.

Fig.12 Hand-foot-clothes monitor

Table 8 Specifications of the hand-foot-clothes monitor

| Item | Description |
|---|---|
| Radiation detected | Beta-rays |
| Detector | Plastic scintillation detector |
| Detection sensitivity | 1.0 Bq/cm$^2$ or less (radiation source: $^{36}$Cl)<br>0.2 Bq/cm$^2$ or less (radiation source: $U_3O_8$) |
| Measurement time | 15 s (can be set within range of 1 to 999 s) |
| Size | Approx. 1,350 (H)×630 (W)×730 (D) (mm), or less |
| Mass | Approx. 80 kg |

ment.

(6) The detector for measuring clothes contamination is made of hard plastic and light in weight.

(7) The low footboard is easy to step onto at the time of measurement.

(8) By using the rear wheels, one person can move the monitor by himself or herself.

(9) The monitor can be separated into three sections, simplifying delivery and installation.

(10) The contamination-preventing film at the foot measurement unit can easily be rolled up and replaced.

(11) A printer is optionally available.

### 6.3 Functions

The two functions of BG measurement and contamination measurement are performed repeatedly. In the case where the BG value has not yet been measured, BG measurement is prioritized and performed for the preset number of times before contamination can be measured. Normally, BG measurement is performed and the value is updated to the latest BG value.

Contamination measurement falls into two categories, hand-foot contamination measurement and clothing contamination measurement, each of which is performed independently. The hand-foot contamination measurement begins when all hand-foot sensors have been detected. After the measurement is completed, the judgment results are displayed on a screen. The probe-shaped detector that is provided is used to measure clothing contamination while surveying the surface of the clothes. Results are displayed on the screen in real-time. In cases where results of the completed contamination measurement are abnormal, the BG verification setting function can be used to check whether the cause is due to the measurer's contamination level or a monitor malfunction.

## 7. Conclusion

In the future, Fuji Electric intends to expand this market by: (1) developing equipment that supports the recent JIS standards established for surface contamination inspection equipment, and (2) developing low cost equipment that is compliant with IEC standards in order to expand sales overseas.

Finally, the authors wish to express their deep gratitude to the electric power companies and all individuals who have provided guidance and cooperation.

# Industrial Measurement Instruments that Use Radioisotopes

**Asao Monno**

## 1. Introduction

Industrial measurement instruments that use radioisotopes (RI) are instruments that harness radioactive rays to measure such parameters as thickness, level, density, moisture and the like. The advantage of such measuring instruments is that they are non-contact, non-destructive and enable online, real-time high-speed measurements. Because the physical properties of RI make these instruments less susceptible to thermal, electrical and vibratory noise sources, these measuring instruments are widely used in such applications as, for example, the mill control in a steel plant, or in production lines at chemical plants and in the plastic and paper industries.

In addition to their use for product inspection purposes, these instruments also are used to production process control systems and have become established as special sensors essential to each production process.

One such example is a hot steel plate thickness gauge that operates automatically under supervision from a process computer and transmits hot state thickness values, with a 50 ms response time, as output for the real time control of a mill, while simultaneously outputting and storing the thickness of the finished product, or in other words the cold state thickness value.

Fuji Electric offers a wide lineup of these instruments, including a gamma ray thickness gauge for use in steel plants, a beta ray thickness gauge for use with plastic and paper, various level gauges, moisture gauges, and the like.

This paper describes a thickness gauge to be housed inside a plate mill, a thickness gauge for hot seamless tubes, and Hitachi-compatible radioisotope-applied measurement instruments.

## 2. Gamma Ray Thickness Gauge Housed Inside a Hot Plate Mill

In the past, thickness gauges for hot plate mills could be installed only at a distance of at least 10 m from either the front or back of the hot plate mill.

The internally-housed gamma ray thickness gauge measures by irradiating gamma rays from inside the mill housing, or more specifically, from the small gap between the rolls of the conveyor at a distance of 2 m from the center of the mill. Conducive to the early application of mill control, this gauge can be used at the stage when the plate is still a slab of a considerable thickness. Furthermore, use of this gauge enhances mill efficiency since there is no need to convey plates a distance of at least 10 m behind the mill in order to acquire mill control information.

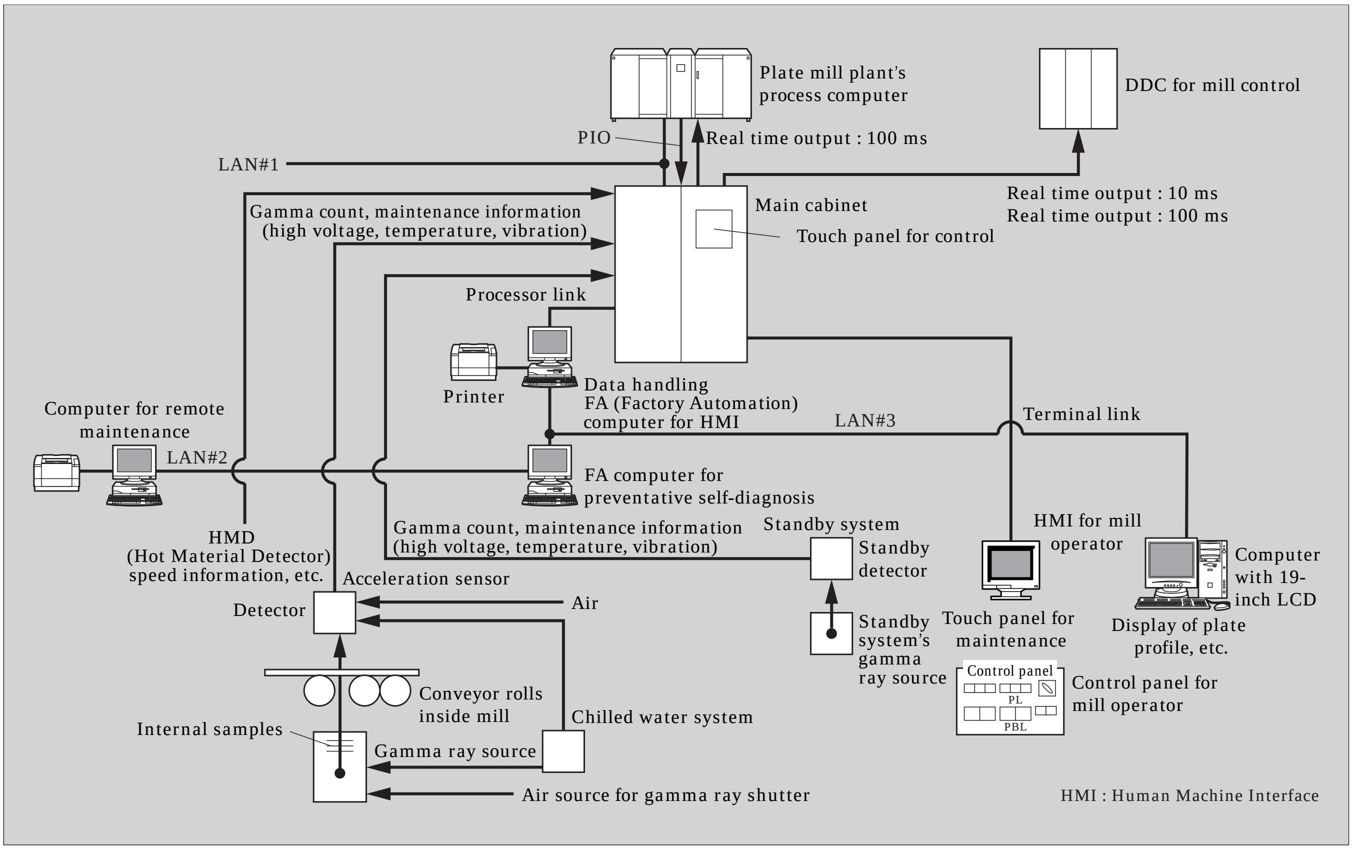
In order to realize such a thickness gauge, in addition to good environmental immunity performance capable of withstanding the harsh environment inside a mill, namely, heat, mechanical shocks, copious amounts of water, adhesion of iron scraps or iron oxides, falling pieces of iron and the like, because the installation site does not allow maintenance to be performed offline, high reliability that differs qualitatively from the reliability of conventional thickness gauges, remote maintenance capability, or the like must also be provided.

Details of the performance of the detector have been reported previously, and therefore, the description below will focus on apparatus performance, sys-

Table 1 Main specifications of the internally-housed gamma ray thickness gauge

| | |
|---|---|
| Radiation source | $^{137}Cs$ 1.11 TBq |
| Detector | Plastic scintillator detector |
| Detector amp | Pulse amp method (digital count method) |
| Detector stabilizing method | Spectra stabilization by near-ultraviolet rays |
| Max. impact acceleration | 735 m/s$^2$ (75 G) |
| Impact reduction ratio | 1/10 or less |
| Thermal resistance | Continuous operation possible inside a hot plate mill |
| Measurement range | Approx. 2 to 150 mm |
| Statistical noise | Ex: 33 µm at 20 mm with 90 % reliability, 0.2 s response |
| Drift | 5 µm / 8 h |
| Instrument response | 10 ms |

Fig.1 System configuration of the internally-housed gamma ray thickness gauge




tem configuration and maintainability.

Main specifications of the internally-housed gamma ray thickness gauge are listed in Table 1, and the configuration of a system currently being constructed is shown in Fig. 1. A 100 ms real time signal is output for mill control, and a fast 10 ms response signal is output to enable more detailed ascertainment of the plate profile. Thickness data is presented to the mill operator via a digital display and a plate profile image is displayed in real time at each pass of the rolling procedure, providing support for instantaneous decision-making.

Remote maintenance, implemented while the gauge is online, uses internal samples to perform automatic multi-point calibration, which includes the zero point (see Published Japanese Patent No. H04-43207). This remote automated calibration, combined with the good stability of the detector, eliminates the need for onsite maintenance of the instrument calibration.

Furthermore, as independent processor is additionally provided to implement a preventative self-diagnosis function which stores in a database various types of maintenance data for the detection and standby systems, as well as real time measurements of vibration, impact, acceleration and the like, and supplies data for the purpose of diagnosing and analyzing failure and to prevent trouble.

Table 2 Main specifications of the tube wall thickness gauge for hot seamless tube mills

| | |
|---|---|
| Radiation source | $^{137}$Cs 1.11 TBq, length 223 mm |
| Detector | Plastic scintillator detector with 350 mm measurement width |
| Detector amp | Pulse amp method (digital count method) |
| Detector stabilizing method | Spectra stabilization by near-ultraviolet rays |
| Measurement range | Outer diameter : 25 to 180 mm<br>Wall thickness : 2 to 45 mm |
| Measurement accuracy | Within 0.2 % of the wall thickness |
| Drift | 0.2 μm / 12 h at 81 mm (outer diameter) and 9.21 mm (wall thickness) |
| Instrument response | 8 ms |

## 3. Tube Wall Thickness Gauge for Hot Seamless Tube Mills

Seamless tubes are high-strength steel tubes suitable for use under severe conditions such as oil well drilling. The tube wall thickness gauge for hot seamless tube mills is designed for mill lines, and especially for mill control in a stretch-reducing mill (that reduces tube diameter and stretches tube wall thickness). This gauge is an automated measuring system that outputs wall thickness measurements in

Fig.2 System configuration of the hot seamless tube wall thickness gauge

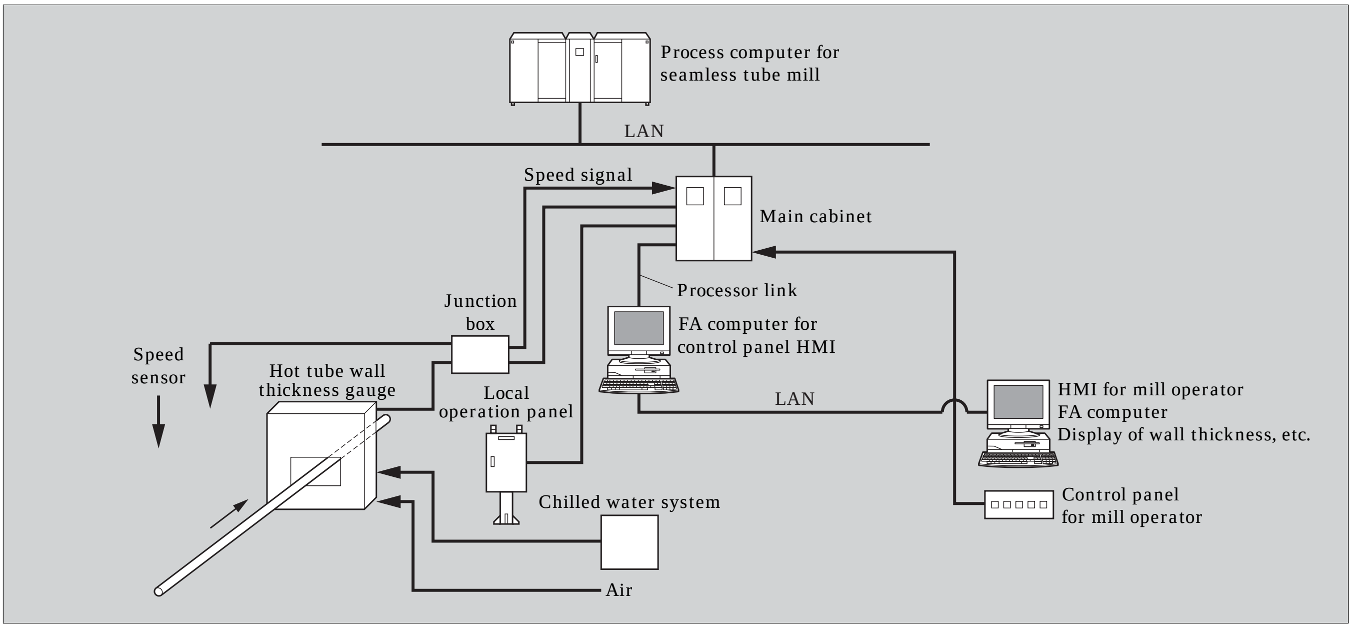



Fig.3 Mechanical part of hot seamless tube wall thickness gauge

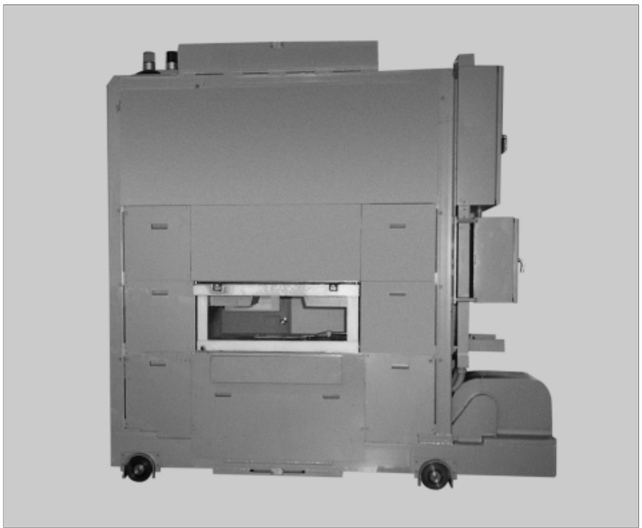
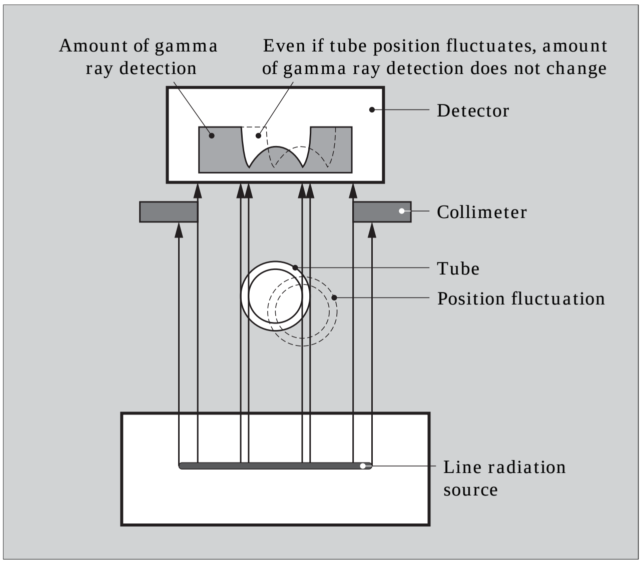


Fig.4 Measurement principle of hot seamless tube wall thickness gauge




real time with a fast 8 ms response speed, while simultaneously determining the top and bottom cut-off locations and storing wall thickness profile information.

As guidance to the mill operator, an image of the wall thickness profile is displayed in real time for each piece. The historical wall thickness profiles of any arbitrary piece in the database can also be displayed upon request.

Table 2 lists the main specifications of the apparatus under construction in FY2004, and Fig. 2 illustrates its configuration. In addition, Fig. 3 shows the appearance of a conventional tube wall thickness gauge, and Fig. 4 illustrates the measurement principle of the hot seamless tube wall thickness gauge. The measurement principle avoids the introduction of measuring error, even in the case where the position of the tube wall fluctuates horizontally or vertically during the course of motion (see Japanese Registered Patent No. 1474136-00).

In order to realize this principle, not only must the gamma ray irradiation field be made uniform, but the detector sensitivity must also be uniform. This challenge was solved by combining an approximately 350 mm-wide plastic scintillator with a special light guide that focuses the scintillation light uniformly and then guides it to a photomultiplier. The electronic circuitry is the same as that of the internally-housed gamma ray thickness gauge, and the near-ultraviolet ray reference method is used as the stabilizing method.

Utilizing two of these detectors, this apparatus

Fig.5 Hitachi-compatible radioisotope-applied measurement instrument

(a) Detector for gamma ray level gauge

(b) Radiation source container (shielding container)

realizes high count values and reduces statistical error with a fast 8 ms response speed.

## 4. Hitachi, Ltd.-Compatible Measurement Instruments

Fuji Electric manufactures and sells equipment that is fully compatible with Hitachi, Ltd.'s radioisotope-applied measurement instruments.

Not only is such measurement equipment interchangeable on the system level, but compatibility is also guaranteed on the component level for such basic components as the radiation source container, detector, electronic circuitry, cables, accessories and the like, making it easy to implement partial equipment upgrades.

In particular, the source capsules, parts, drawings and manufacturing processes of Fuji Electric's and Hitachi's radiation source containers are completely identical. This is beneficial to the user for ensuring compliance with the applicable laws and regulations.

Since the start of marketing activities under the terms of cooperation between Hitachi and Fuji Electric, these instruments have already been delivered to several tens of customers, and in all cases, the equipment is operating stably.

Figure 5 shows an example of a compatible instrument.

## 5. Conclusion

The internally-housed gamma ray thickness gauge achieves better durability in terms of impact resistance and thermal resistance than Fuji Electric's previous thickness gauges, and also realizes stable maintenance-free operation, high-speed response, and a database function. In the future, Fuji Electric intends to apply these technologies to its entire line of thickness gauges and to provide systems with even higher levels of reliability.

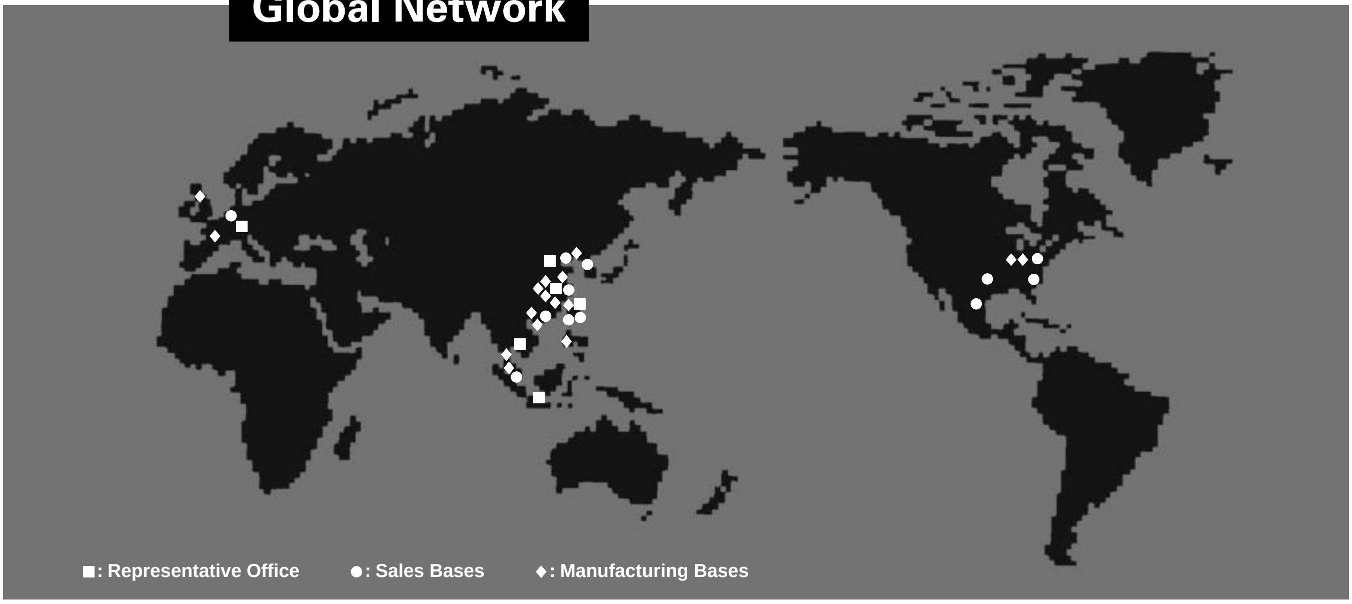
Because the hot seamless tube wall thickness gauge handles tube diameters of approximately 180 mm, it is intended for rather large-scale systems. In the future, Fuji Electric plans to develop lower cost equipment for smaller tube diameters or systems having simpler configurations.

Level gauges and density gauges are available both as Fuji Electric models and as Hitachi-compatible models. Future product development will promote the advantages of each.

# Business Outline of the Each Operating Company

| Company | Business Outline |
|---|---|
| Fuji Electric Systems | Fuji Electric Systems strives to inject new value into social infrastructure by offering industry-leading products and services in the industrial, public sector, energy, and transport fields. As a solutions provider in the areas of information, the environment, energy and services, Fuji Electric Systems works hand in hand with customers to make their businesses a success. |
| Fuji Electric FA Components & Systems | Fuji Electric FA Components & Systems supplies a range of components, as well as small and medium-sized systems using these components, to customers in the industrial automation field. The company's extensive array of products, which demonstrate world-leading levels of quality and performance, include electrical distribution control, drive, power electronics, motion, and human-machine interface (HMI) components and devices. Underpinned by this product portfolio and a lineup of related services, the company is working to create new value for customers. |
| Fuji Electric Device Technology | Leveraging its core competence —technological expertise— Fuji Electric Device Technology offers high-quality, high value-added products in the semiconductor, storage and imaging device fields. The company's ultimate goal is to create a range of world-leading products that satisfy customer needs for high-performance, compact and energy-efficient products in the industrial, automobile and information device fields. |
| Fuji Electric Retail Systems | Focusing on three core businesses: vending machines, where Fuji Electric has the leading share in the domestic market, cold-chain equipment, and coin & currency systems, Fuji Electric Retail Systems is working to support society through the creation of innovative and convenient retail spaces. The company also strives for maximum customer satisfaction by offering new solutions and services that enhance vending machine operations and store management efficiency in many areas of the retail sector. |

# Global Network

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