Radiation Management Solutions Contributing to Safety and Security

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ABSTRACT

Fuji Electric provides facilities and local governments that handle radioactive materials with radiation management solutions to contribute to safety and security. In environmental radiation monitors, which were proved useful to support the recovery from the Great East Japan Earthquake, we have developed monitoring posts that use diversified communication functions to improve continuous monitoring capability during disaster and real-time dosimeters with improved detection accuracy and stability. For environmental radiation monitoring telemetering systems, which collect measurement data, including radiation doses, and display them on the screen, we have developed a platform that can be expanded to meet customer needs. In addition, we have developed the detector for alpha-ray aerosol monitors that improves alpha-ray measurement performance by reducing noise and improving resolution.

1. Introduction

Climate change caused by global warming is a crucial issue and a major threat to create a sustainable society. Various measures are implemented around the world to overcome this problem. In recent years, rapid changes in world situation have exposed major risks to the stable energy supply. In particular, Japan is not rich in energy resources, and rising fuel costs and other factors are beginning to have a significant impact on people's lives and business activities. Under the circumstance, the government of Japan has announced that it will promote decarbonization, shifting social and industrial infrastructure away from reliance on fossil fuels to focus on clean energy. The government is going to change policy to decarbonized society with stable energy supply.

Japan has announced that their decarbonization initiative includes not only breaking away from excessive dependence on fossil fuels, but also the use of nuclear energy as a highly decarbonized power source, promoting the shift to a resilient energy supply-and-demand structure.

For use of nuclear energy, the government has indicated a policy to maximize utilization of existing facilities, focusing on reactivation of nuclear power plants following safety evaluations. Based on lessons learned from the accident at the Fukushima Daiichi Nuclear Power Station, plan is safety first by cooperating closely with local residents.

As a manufacturer of comprehensive radiation measuring instruments, Fuji Electric has developed and delivered various instruments and systems for radiation control, and contributes to safe operation of nuclear facilities.

Since the Great East Japan Earthquake, Fuji Electric has delivered real-time ambient dose equivalent meter to support the reconstruction of the Fukushima area, developed disaster-resistant radiation monitors, and redundant communication lines. This paper describes proposal for radiation control, which contribute to safety and security.

2. Overview of Radiation Control Solutions

Instruments used for radiation control are classified as monitor of personal radiation exposure control, surface contamination monitors, environmental radiation monitors, or facility radiation monitors. These monitors work in corporation with radiation monitoring panels and computer systems to manage measurements. Figure 1 shows a image that illustrates a radiation control system.

The features of each monitor and of typical detec-

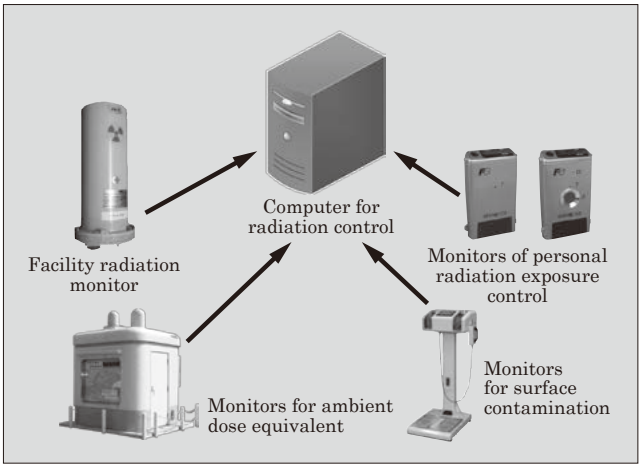

Fig.1 Radiation control system image

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tors are as follows:

(1) Monitors for personal radiation exposure control

Monitors for personal radiation exposure control measure the external and internal exposure of workers engaged in work at nuclear facilities and related facilities. External exposure means exposure to radiation from outside the body, and internal exposure means exposure to radiation from radioactive materials that enter the body. Typical monitors include monitors of personal radiation exposure control and whole body counters.

(2) Monitors for surface contamination

Monitors for surface contamination measure whether radioactive contamination exists or not in workers and objects. Nuclear facilities have areas called radiation controlled areas where radiation exposure is properly controlled, and presence of monitors of clothes surface for beta rays is measured when workers exit or bring out objects from these areas. Typical monitors include radioactive surface monitors for the human body, as well as survey meters.

(3) Monitors for ambient dose equivalent

Monitors for ambient dose equivalent are mainly used to measure ambient doses around nuclear facilities. Typical monitors include real-time ambient dose equivalent meter and monitoring posts.

(4) Monitors for radiation in nuclear facilities

Monitors for radiation in nuclear facilities measure ambient radiation doses in nuclear facilities and concentration of radioactive materials emitted from facilities. Typical monitors include area monitors, gas monitors, and aerosol monitors.

In recent years, needs increase that radiation monitoring at boundary and around nuclear facilities. After Chapter 3, it and subsequent chapters describe the latest monitors for ambient dose equivalent and software platforms of environmental radiation monitoring telemeter systems. These chapters describe facility radiation monitors that are being upgraded in preparation for reactivation of nuclear power plants.

3. Monitors for Ambient Dose Equivalent

3.1 Monitoring posts

(1) Overview

Monitoring post is monitor that measures ambient doses. Figure 2 shows the appearance of a monitoring post. The monitoring post consists of detector, measurement unit, and external housing. Although monitoring posts are installed in various environments, Fuji Electric's monitoring posts can adapt to customer requirements, as there are two types: one with an all-in-one radiation measurement unit and calculation unit, and the other in which these two units are separate. These monitoring posts are equipped with a sodium iodide (NaI) scintillation detector. The NaI scintillation detector consists of a NaI scintillator and a photomultiplier tube. Electrons inside the scintillator are excited by incident radiation and then return to base to emit light. This monitor measures radiation by amplifying this light through a photomultiplier tube and detecting it as an electrical signal. The measurements processed by the measurement unit are transmitted to nuclear facilities and radiation control systems managed by central agencies and municipalities for remote monitoring. Table 1 shows the specifications of the monitoring post.

(a) All-in-one type

(b) Separated type
Detection Assembly with control unit:
type A: non-display
type B: with display

Fig.2 Monitoring post

(2) Features

(a) Energy compensation and temperature compensation functions

The measurement results of the NaI scintillation detector depend on the energy of gamma rays and the ambient temperature, and this equipment corrected them using the G(E) function weighting operation method. For temperature dependence, a thermometer is installed inside the detector to compensate for output changes by temperature changes. This compensation enables the variation of response within ±10% (100 keV to 3 MeV, ^{137}Cs) and the temperature characteristics within ±5% (–10°C to +45°C).

Table 1 Monitoring post specifications

Category	Specifications
Radiation detected	Ambient gamma rays
Detector	Temperature compensation type 2" ϕ × 2" NaI (Tl) scintillation detector
Measurement range	Background level to 100 μGy/h
Energy range	50 keV to 3 MeV
Limit of variation/ Reference source	±10% (^{137}Cs)
Variation of response	Within ±20% at 50 to 100 keV ±10% at 100 keV to 3 MeV (^{137}Cs)
Energy resolution	10% or less (for the high output wave of ^{137}Cs photopeak)
Detector temperature range	Within ±5% at –10°C to +45°C
Power supply	100 V AC ±10%, 50/60 Hz

Fig.3 A NaI scintillation detector

(b) Automatic correction function for gain change

When the NaI scintillation detector is used for long time, long-term drift of components may cause changes in gain and errors in measurement results. To handle this problem, Fuji Electric's detectors can correct automatically the gain using the 40 K peak channel in nature as the reference channel.

(c) Integration of the detector and the measurement unit

In conventional monitoring posts, the detector and the measurement unit are separate, but in this monitoring post, the measuring unit function is built into the detector to minimize size. Figure 3 shows a NaI scintillation detector. To meet the energy analysis requirements for gamma rays, this monitoring post is equipped with the multi-channel wave height analysis function used in conventional measurement units. The product also complies with the relevant standards [Equipment for continuously monitoring gamma radiation in the environment: JIS Z 4325 (2019)] and No. 17 of the Radioactivity Measurement Method Series.

(d) Diversification of communication functions

It is important for monitoring posts to be responsive to the diversification of communication functions, as their role becomes more crucial in disaster. The demand for the diversification of communication functions is increasing since the Great East Japan Earthquake, and Fuji Electric has continued to respond accordingly. In addition to the wired and cellular phone networks, the monitoring posts can support satellite communication networks and enable continuous monitoring even in congestion or cutoff of general lines.

3.2 Real-time ambient dose equivalent meter

(1) Overview

While monitoring posts are installed around nuclear facilities for main purpose of measuring changes in environmental radiation doses caused by the facilities, real-time ambient dose equivalent meters are installed mainly in schools, parks, and government offices, and are responsible for ensuring safety and security for residents. Figure 4 shows a real-time ambient dose equivalent meter.

The device consists of a radiation detector, a measurement unit, a communication unit, a solar panel, a battery, and a dose indicator, and has environmental radiation measurement, communications, and dose rate indication functions. In addition to commercial power supply, the power can be supplied by solar panels and internal batteries. This enables continuous measurements even during blackouts. Table 2 shows the specifications of the real-time ambient dose equivalent meter.

(2) Features

(a) Improved detection performance and enhanced stability of semiconductor detectors

The real-time ambient dose equivalent meter is equipped with a newly developed semiconductor detector. This semiconductor detector has a larger detection surface than the previous product[1], and its arrangement has been optimized, improving accuracy. Redundant electromagnetic shield and improved noise immunity have reduces the influence of various electromagnetic waves, contributing to measurement stability.

(b) Improved environmental resistance

The radiation detector, measurement unit, and communication unit are housed in reinforced plas-

Fig.4 Real-time ambient dose equivalent meter

Table 2 Real-time ambient dose equivalent meter specifications

Category	Specifications
Radiation detected	Ambient gamma rays
Detector	Semiconductor detector
Measurement range	Background level to 99.99 μSv/h
Energy range	50 keV to 3 MeV
Relative error	±20% (based on 60 keV to 1.25 MeV, ^{137}Cs reference)
Variation of response	±25% (based on 60 keV to 1.25 MeV, ^{137}Cs reference)
Operating environment	Non-weather protected, fanless
Power supply	100 V AC ±10%, 50/60 Hz

tic enclosure, but there are concerns about negative effects of infiltration of rainwater and moisture on electronic devices in stormy weather. The electrical parts and devices built in enclosure in small boxes by function with moisture-proof and waterproof finish. They make lower failure rate, and longer service lifetime by protecting from moisture.

4. New software platform for environmental radiation monitoring telemeter systems

(1) Overview

Radiation monitors such as monitoring posts measure radiation and radioactive materials emitted from nuclear power facilities 24 hours per day, 365 days per year. Measured data are collected by environmental radiation monitoring systems controlled by nuclear power facilities, central ministries, and municipalities, and used for monitoring operations. For residents near nuclear facilities, the data are displayed in real time on large-screen at government offices. The data are informed on internet. Fuji Electric has contributed well to providing systems, as well as development and manufacturing of radiation monitors. To meet recent diversification of customer requirements, we have developed a new software platform compatible with cloud systems and standard interfaces.

(2) Features

(a) Cloud migration

Conventional systems were on-premises mainly, in which customers own and manage infrastructure equipment such as servers. In recent years, plans to implement cloud systems have increased by business continuity plans (BCP) and system scale extensibility. The new software platform uses open source databases and middleware to ensure compatibility with next mainstream hosting clouds, reducing initial implementation and maintenance costs.

(b) Providing of various monitoring methods

The system screen is for management radiation doses in area to monitor the measurement data. The conventional system used Internet Explorer*1 as the standard browser with single window screen, causing inconvenience. HTML Living Standard based new development supports current mainstream browsers such as Microsoft Edge*2 and Google Chrome*3, and can also be displayed on smartphones and tablets. The operation screen offers multi-window mode to improve efficiency of monitoring operations. Figure 5 shows the displayed content of new platform using JavaScript*4. For front-end browser screen development, conventional platforms used JSP and Java*5 applets. New software platform uses JavaScript to implement a browser based on the HTML Living Standard, which enables the display of various contents such as videos and graphics.

(c) High scalability system

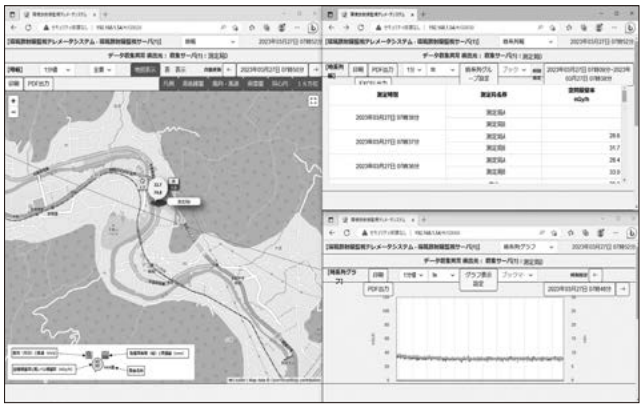

Fig.5 Display on new platform with JavaScript

Environmental radiation monitoring telemeter system renewal sometimes require security enhancement, operability improvements, function enhancement, and modification. Resources are often required to use the existing system for continuity of operations, and problem is that systems are hard to expand. The new software platform uses JavaScript Object Notation (JSON) as an interface to unify communications in several processes, making it easier to extend to meet customer requirements. There are JSON libraries adapt other programming languages enable to use existing resources.

5. Alpha-Ray Aerosol Monitor

(1) Overview

Nuclear power plants generate electricity by energy from fission of uranium, and plutonium as artificial radionuclide is produced on the process. The spent nuclear fuel contains uranium and plutonium that can be reused as fuel. Reprocessing extracts the uranium and plutonium and mix together to form the fuel called mixed oxide (MOX).

Japan is not rich in energy resources and is working for realization of a plutonium-thermal system with this MOX fuel in conventional nuclear power plants. To use plutonium safely and effectively, it is important to

*1 Internet Explorer is a trademark or registered trademark of Microsoft Corporation.

*2 Microsoft Edge is a trademark or registered trademark of Microsoft Corporation in the United States and other countries.

*3 Google Chrome is a trademark or registered trademark of Google LLC.

*4 JavaScript is a trademark or registered trademark of Oracle Corporation and its subsidiaries and affiliates in the United States and other countries.

*5 Java is a trademark or registered trademark of Oracle Corporation and its subsidiaries and affiliates in the United States and other countries.

improve the measurement of alpha rays emitted from plutonium, and Fuji Electric has developed an alpha-ray aerosol monitor that measures plutonium more accurately. Figure 6 shows a aerosol monitor image and an alpha-ray aerosol monitor. The alpha-ray aerosol monitor absorbs particle in a sampled air using the filter paper on precipitator to measure alpha rays.

(2) Features

(a) Noise reduction

Conventional aerosol monitors send measured pulse signals from radiation detector to separate measurement unit. But this way would mix noise in pulse. The alpha-ray aerosol monitor features an all-in-one detector and measurement unit to reduce noise contamination in communication line. Measurement and subsequent units use a digital communication system to reduce noise.

(b) High resolution

Detector is placed on filter paper on precipitator to measure alpha rays. Alpha rays are emitted at various angles from filter paper, and detector incident distances are various. As a result, there are fluctuations in the measured energy. This means that the resolution becomes lower, making it difficult to distinguish artificial radionuclides from radon and thoron, which are natural radionuclides. Alpha ray incident component of new detector has a honeycomb structure. Diagonally incident Alpha rays are blocked, and vertical incidents can be detected only (see Fig. 6). As a result, the range distance of alpha rays incident on detector is almost same, and this has reduced variation of measurement energy and achieved high resolution. Figure 7 shows measurement results of americium 241 (^{241}Am), an alpha-ray emitting radionuclide, and radon (Rn) and thoron (^{220}Rn), natural radionuclides. These results show that americium 241 has been measured separately from radon and thoron, which are natural radionuclides.

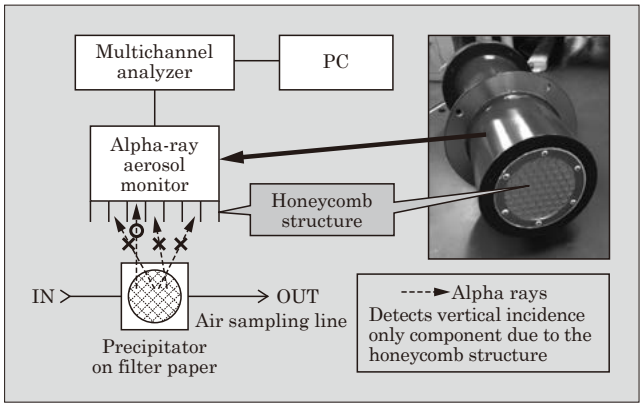

Fig.6 Aerosol monitor configuration and an alpha-ray aerosol monitor

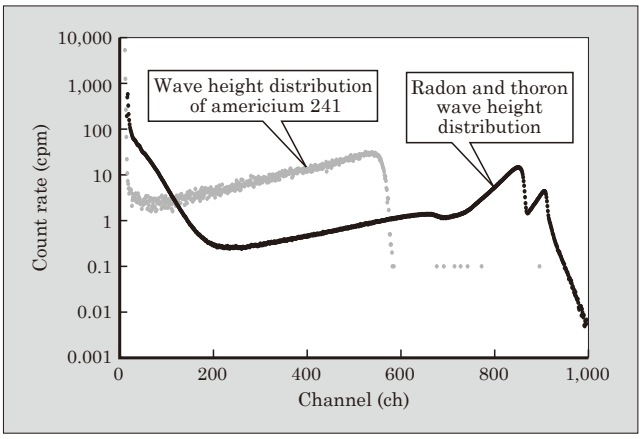

Fig.7 Measurements of americium 241, radon, and thoron

6. Postscript

This paper proposed radiation control, which contribute to safety and security. The achievement of decarbonized society and stable energy supply require to utilize nuclear energy. Fuji Electric, a manufacturer of comprehensive radiation measuring equipment providing from radiation detectors to systems, has innovated technologies to contribute to safe operation of nuclear power facilities.

References

(1) Maekawa, O. Radiation Management Service Solutions Contributing to Safety and Security. FUJI ELECTRIC REVIEW. 2020, vol.66, no.1, p.65-71.

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