ABSTRACT

A new body surface monitor for monitoring the surface radioactive contamination of the general population living and working around the site in the early stages of a nuclear accident has been designed. The body surface monitors will be installed in a medium-sized bus with a thyroid counter and moved to the place where measurement is required.

The different characteristics needed for the body surface monitor to measure the general population from those of monitors used in nuclear power stations are discussed.

The detection sensitivity of the plastic scintillator was measured under various geometric conditions and the Minimum Detectable Activity (MDA) was found to be lower than 1 Bq/cm² in a 10-second count time.

Two body surface monitors can measure 2,880 persons in eight hours.

INTRODUCTION

In the early stages of a nuclear accident, it is necessary to monitor the surface radioactive contamination of the general population living and working around the accident site before measuring ¹³¹I in the thyroid gland.

Measuring the surface contamination of people by a conventional GM survey meter has the following problems.

1. The sensitive area of most GM survey meters ranges from 5 to 20 cm². Although the time constant of monitoring is set to 1 second, it takes several minutes to measure the entire surface of a person.

2. When the time constant is set to 1 second, the standard deviation of measurement becomes more than 60% under the natural background radiation level. It needs an operator’s long experience and know-how of radiation measurement to check if the person is contaminated or not while they scan the survey meter probe on the surface of people. It is difficult to obtain homogeneous contamination judgement.

3. To measure surface contamination of people by manually handling a survey meter probe for a long time imposes a burden on the operator.

4. Measured data are not recorded. Statistical evaluations are impossible.

A body surface monitor resolves the above mentioned problems. It monitors radioactive contamination of the whole body quickly with high efficiency. At present, many body surface monitors have been installed at the exits of the controlled area in nuclear power stations and utilized to check automatically contamination of the surface of workers.

| Table 1  Body surface monitor compared to survey meter |
|-----------------|-----------------|
| Time required for measuring | 10 seconds | Approx. 3 minutes |
| Accuracy | High | Low |
| Construction | Large and heavy | Small and light |
| Objects to be measured | Slightly restricted | Not restricted |
| Installation | Fixed | Portable |
| Operator required | Two operators | Many operators |
| Data storage | Possible | Impossible |
| Cost | Expensive | Low |

We have designed a new body surface monitor to be installed in a medium-sized bus.

DESIGN OF THE BODY SURFACE MONITOR

The body surface monitor for radioactive contamination of the general public resulting from an accident must have different characteristics, which are comparable to those of monitors used in power stations.

1. To be able to measure various body shapes and sizes including children and elderly people.

2. To be able to detect surface contamination level of 1 Bq/cm² within 10 minutes. This level is one fourth
of the regulatory level for workers who leave the controlled area.

(3) To avoid giving the person the psychologically negative response of being in a small and confined space.

(4) To monitor ambient gamma background level continuously by an area monitor installed near the body surface monitor.

(5) To determine whether the person has been contaminated or not by the body surface monitor independently, not by a computer which is used for statistical data storage.

Plastic scintillators are preferred for the body surface monitor because they need no counting gas and can start operation quickly for an emergency.

Eleven large-area, plastic scintillators are used for monitoring; two for the hands, two for the feet, three for the front of the body, three for the back, and one for the head. Both of right and left sides of the body are opened not to give the person the psychological pressure and for easy entering into the monitor and leaving. The detector for the head moves automatically in a range of 130 to 190 cm according to the height of the person. The back detector can manually be adjusted forward and back. A pre-amplifier and discriminator board is attached to each detector.

Major specification items of the surface contamination monitor are shown in Table 2.

### Table 2  Major specifications of the surface contamination monitor

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detectors</td>
<td>Eleven plastic scintillators</td>
</tr>
<tr>
<td>Measuring object positions</td>
<td>Hands, feet, front of the body, back and head</td>
</tr>
<tr>
<td>Counting range</td>
<td>1 to 999,999 counts</td>
</tr>
<tr>
<td>Counting time</td>
<td>1 to 999 seconds</td>
</tr>
<tr>
<td>Moving range of head detector</td>
<td>1,300 to 1,900 mm, automatically adjusted</td>
</tr>
<tr>
<td>Moving range of back detector</td>
<td>330 to 500 mm, manually adjusted</td>
</tr>
<tr>
<td>Dimensions and Weight</td>
<td>860(W) x 1,200(D) x 2,200(H) mm, 700 kg</td>
</tr>
</tbody>
</table>

**EXPERIMENTS AND MINIMUM DETECTABLE CONTAMINATION LEVEL**

The detection sensitivity of surface contamination measurement changes according to the geometric conditions between the radiation detector and the contaminated place. We measured the detection sensitivity under various conditions to confirm the MDA of the monitor.

We used a 10 cm-square $^{36}$Cl standard radiation source whose electron emission rate is $1.64 \times 10^3$ s$^{-1}$ and a 52 cm by 31 cm plastic scintillator.

The MDA is expressed as follows (1).

$$A = C \times N$$

$$N = \frac{k}{2} \times \left\{ \frac{k}{t_s} + \sqrt{\left( \frac{k}{t_s} \right)^2 + 4 \times N_b \times \left( \frac{1}{t_s} + \frac{1}{t_b} \right)} \right\}$$

where

- $A$ = MDA (Bq/cm$^2$);
- $C$ = calibration coefficient (Bq/cm$^2$/s$^{-1}$);
- $N$ = count rate which defines the limit of background fluctuation (s$^{-1}$);
- $k$ = time of the standard deviation of background ;
- $t_s$ = counting time for routine measurement (sec);
- $t_b$ = counting time for background (sec);
- $N_b$ = background count rate (56 s$^{-1}$).
Figure 1 shows changes of detection sensitivity and the MDA measured when we put the standard radiation source at the various positions on the vertical axis at the center of the plastic scintillator.

![Figure 1](image1.png)

Figure 2 shows changes of detection sensitivity and the MDA measured when we put the standard radiation source at the various positions on the parallel plane to the scintillator at 20 cm distance.

![Figure 2](image2.png)

It is possible to describe that the MDA of this body surface monitor is lower than 1 Bq/cm$^2$ in a 10-second count time for $^{36}$Cl when the distance between the surface of the body of the person and the scintillation detector is within 20 cm.

**DESIGN OF THE BUS**

Installation of surface contamination monitors at fixed places restricts measuring only to people who live near the places. Moreover, it cost much to install the monitor at each nuclear facility site. Because automobiles move more than several hundred km in half a day, it is preferable to prepare a few surface contamination monitoring bus at each district which contains two or three nuclear facility sites.
We have studied a bus in which two surface contamination monitors and a thyroid counter are installed.

Two surface contamination monitors are placed side by side in the central part of the bus. People to be tested enter at the front door and wait at the waiting corner. These people hear about the measuring procedures while watching the persons who are inside the monitor. There is space for several persons at the waiting corner. After the measurement of either person is finished, the next person enters into the monitor and puts his feet on the detectors for feet and inserts both hands into the detectors for hands. The operator pushes the start button for measurement.

After one’s measurement is finished, he goes out of the monitor and exits from the rear door of the bus. The entire processing time will be less than 20 seconds per person.

The thyroid counter can also measure the thyroid gland of the person, if necessary.

In this way, two operators can measure 2,880 people in an eight-hour period. Figure 3 shows the arrangements inside the bus.

*Figure 3 Arrangements inside the bus*

**SUMMARY**

We have designed a body surface monitor for the general population at a nuclear accident with an MDA which is lower than 1 Bq/cm² in a 10-second count time. We can move the bus containing two surface monitors and a thyroid counter to the affected area.

It is possible to measure 2,880 persons in eight hours.

**REFERENCES**