AUTOMATIC MEASUREMENT OF LOW LEVEL CONTAMIANTION ON CONCRETE SURFACES

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ABSTRACT

Automatic measurement of radioactivity is necessary for considering cost effectiveness in final radiological survey of building structures in decommissioning nuclear facilities. The RAPID (radiation measuring pilot device for surface contamination) was developed to be applied to automatic measurement of low level contamination on concrete surfaces.

The RAPID has a capability to measure contamination with detection limit of 0.14 Bq/cm^2 for ^{60}Co in 30 seconds of measurement time and its efficiency is evaluated to be 5 m^2/h in a normal measurement option. It was confirmed that low level contamination on concrete surfaces could be surveyed by the RAPID efficiently compared with direct measurement by workers through its actual application.

INTRODUCTION

In the final stage of decommissioning nuclear facilities, building structures are demolished to be green field conditions if dismantling is chosenas a decommissioning strategy. However, since building structures are generally made from massive concrete materials in nuclear facilities, it is not a rational way to treat all concrete materials arising from its demolition as radioactive waste. It is therefore necessary to segregate only radioactive parts from building structures to treat remaining concrete materials as non-radioactive waste. In order to separate only radioactive parts from building structures, accurate identification of radioactivity parts by radiological characterization may be an important process.

In addition, confirmation measurement of radioactivity (final radiation survey) must be conducted so as to confirm that there is no radioactive parts in the remaining concrete materials in order to treat the remaining concrete materials as non-radioactive waste. For example, in the JPDR (Japan Power Demonstration Reactor) decommissioning program the final radiation surveywas conducted to show that there are no artificial radioactive nuclides produced by operation in the decontaminated area (1, 2). Gross of beta and gamma-rays was measured with handy type detectors in this process. In addition, it was found in some case that non-contamination was not easy identified counting rate is small with large fluctuation of background level. Moreover, the sensitive window area (164 cm^2) of the detector used was small so that a lot of time was spent in the final radiation survey in the JPDR decommissioning program because the area to be measured was large.

Based on the lessons learned in the JPDR final radiological survey, R&D started to develop were efficient radiation measurement techniques (3). In development of radiation detector, new concept was created to identify only beta-rays by separating beta and gamma-rays from contaminants. Automatic measurement of radioactivity is also applied to reduce time required for final radiation survey. Then, the RAPID (radiation measuring pilot device for surface contamination) was manufactured to realize the automatic measurement of low level contamination on concrete surfaces (4, 5).

This paper describes development of automatic measurement technique for low level contamination on concrete surfaces.

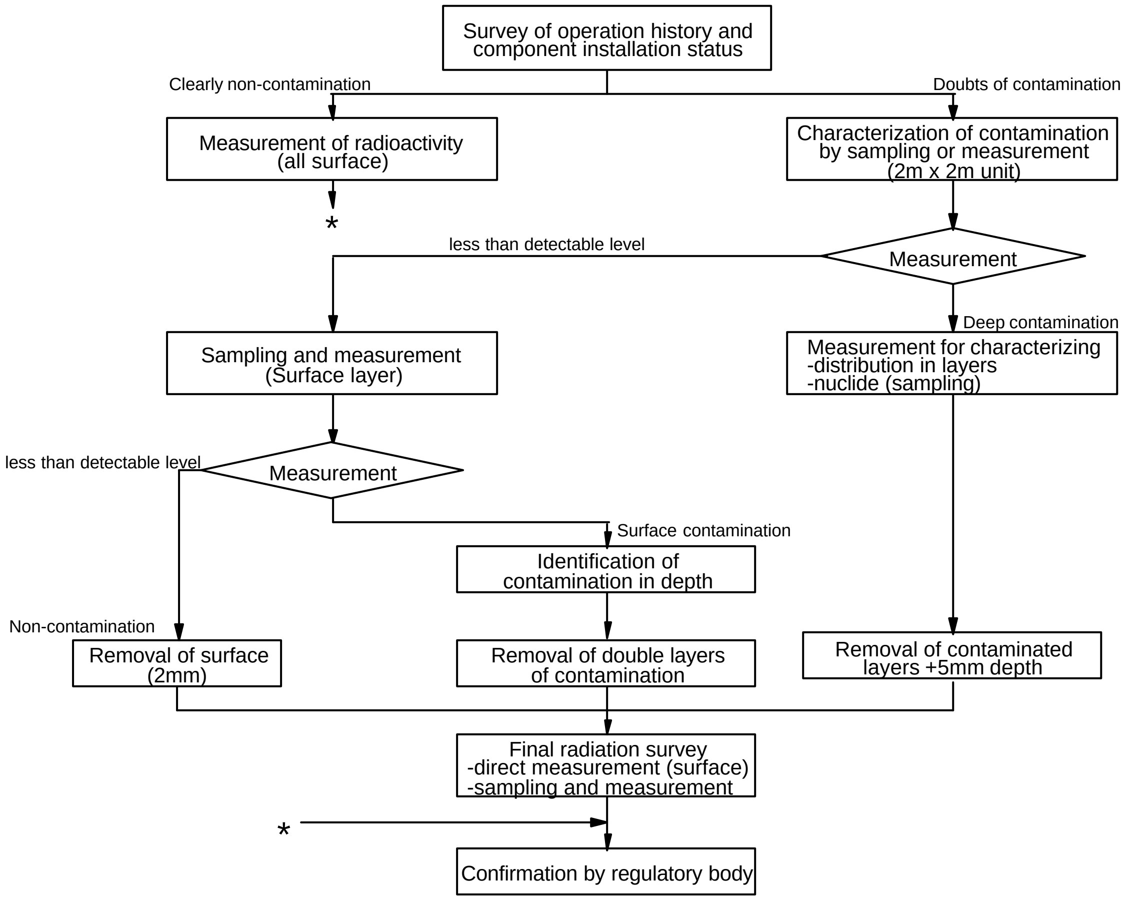

Fig.1. Basic flow for identifying non-radioactive materials

EXPERIENCE IN JPDR DECOMMISSIONING PROGRAM

The concept of classifying non-radioactive materials, which was studied by the Nuclear Safety Commission, is only applicable way to allow conventional demolition of building. The classification of non-radioactive materials was actually conducted in the JPDR decommissioning program based on the concept. Figure 1 shows the basic flow for identifying non-radioactive materials in the JPDR decommissioning program.

Several steps were applied to demolish the building with conventional technology. At the first step, facility operation history was surveyed to identify contamination areas. Next, the contamination on building surfaces was characterized in detail by sampling and measurement. Samples were taken in 2 by 2 m block base; contamination depth and nuclides were checked in the process. Contamination maps were then drew on the basis of the measurement. The building surfaces were decontaminated; the surface layer in 2 mm depth was removed even in non-contaminated areas, the contaminated layer was segregated with twice of measured contamination depth in surface contamination areas, and the contamination layer was removed with 5 mm margin of its depth in deep contamination areas.

The final radiation survey was conducted by two steps; first, direct measurement by handy type detectors, second, sampling and measurement of gamma-ray spectra. The survey meter is capable of 0.4 Bq/cm^2 for beta-emitters under normal background. The direct measurement was performed on every 0.8 by 0.8 m block moving the survey meter and the highest counting rate was identified in each block to measure its counting rate. The counting rate was compared with the background level to be confirmed that there was no significant radioactivity in the block. After the direct measurement, samples were taken from each room for confirmation of that radioactivity level is less than 3 Bq/kg.

The total number of measurement on building surfaces resulted in more than 50 thousand in total. Manpower expenditure was 4,800 man-days during the final radiation survey. Work efficiency of the final radiation survey was 4.96 m^2/man-day. The measurement of radioactivity by workers was found to be costly them. The RAPID was manufactured to reduce measurement time and to detect low level contamination on concrete surfaces.

The design concept of RAPID is described in the following chapter.

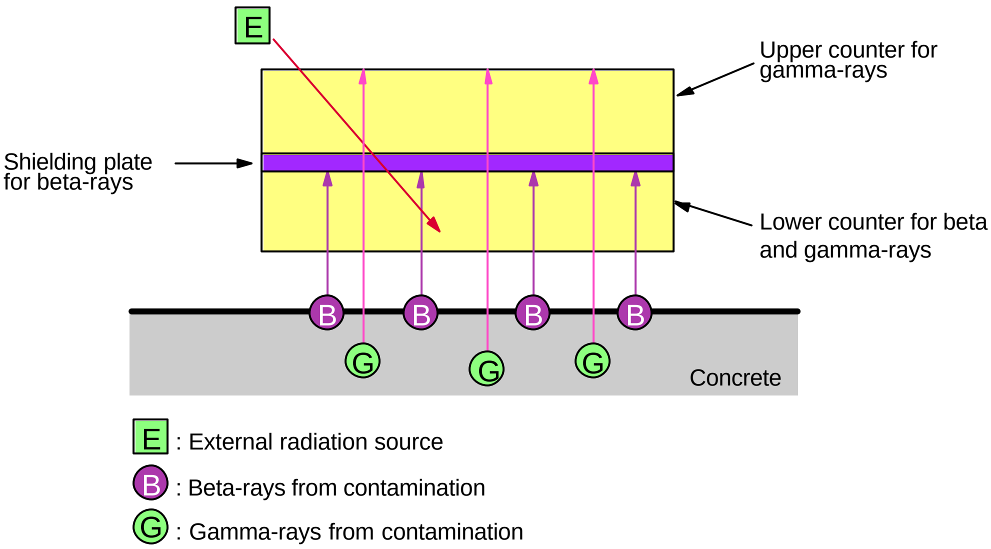

Fig. 2. Outline of method for measurement of radioactivity

DESIGN CONCEPT OF RAPID

Radiation Detector

In the JPDR (Japan Power Demonstration Reactor) decommissioning program the final radiation survey was conducted to show that there are no artificial radioactive nuclides produced by operation in the decontaminated area. Gross of beta and gamma-rays was measured with handy type detectors in this process. In addition, it was found in some case that non-contamination was not easy identified counting rate was small with large fluctuation of background level. To achieve high sensitivity under natural background conditions, the method to discriminate beta-rays from both gamma and beta-rays is applied to the new radiation detector. Figure 2 shows outline of method for measurement of radioactivity. Beta and gamma-rays are counted by a lower counter and gamma-rays are counted by an upper counter in double layer gas flow type counters, then only beta counting rate is evaluated by processing the data.

Driving Unit

The driving unit was designed to be able to move omnidirectionally according to route plans with self-position identification system to move for measurement accurately.

The following functions were provided for the driving unit. A dual-wheeled caster-drive mechanism was adopted as a mobile mechanism. It was designed to move without restriction against the moving direction and to allow prompt omnidirectional movement. The maker unit, which has a digital mark pattern of a circle at its top part, was prepared for self-position identification. The driving unit has a capability to correct its position if an orbital error is detected by obtaining an image of the digital mark pattern of the circle.

DEVELOPMENT OF RAPID

Radiation Detector

The radiation detector of the RAPID has 2 horizontal rows of 8 units each. The size of one unit is 100 x 100mm to identify relatively small partial contamination such as hot spots. A shielding plate made from aluminum of 2mm in thickness is installed between the upper counter and the lower counter in order to quantify only beta-rays by separating from gamma and beta-rays emitted from ^{60}Co and others. Six anode rods (diameter: 0.03mm) made from the tungsten plated with gold are installed in each counter. PR gas (Ar 90% and CH_4 10%) is full of each counter as a counting gas.

Driving Unit

The driving unit has two parallel wheels that are driven individually similar to those of a dual-wheeled differential drive vehicle as a mobile mechanism. The driving unit rotates in the direction tangential to the circle having a center at the mid-point of the two driving wheels.

The CCD camera is installed at the top of the driving unit. The CCD camera can rotate to any direction by a pan and tilt mechanism. The resolution of an image obtained by the CCD camera is 640 x 480 pixels. The marker unit, which has a digital mark pattern of a circle at its top parts, is prepared for self-position identification. The digital mark pattern has 11 bits of information, and the differential height between the mark pattern and the camera is designed to be about 1 m in this system. The digital mark pattern consists of a circle line on a horizontal plane with angular information on its outer periphery. The angular information is given for each segment dividing the outer periphery into equal parts, i.e. binary numbers expressed by the white and black tones.

Control System

The control system consists of a host computer and an operation control unit.

Route plans are made using the host computer. The route plans are gives as a set of positions relating to the planed measurement areas. The region for measurement is determined by one rectangular area and/or the combination of two rectangular.

The operation control unit controls the position and posture of the driving unit according to the route plans as follows. The CCD camera obtains an image of the digital mark pattern on the circle of the marker unit. After processing the image, a distance and an angle on the polar coordinate, of which the origin is located in the center of the circle, are calculated to identify the present driving unit position. The RAPID has a capability to correct a driving unit's position if an orbital error is detected by the self-position identification. Thus, the driving unit can move accurately according to the route plans, which are given as a set of positions relating to the planned measurement areas. The operation control unit controls rotating angle and velocity of driving wheels according to the route plans.

Automatic measurement is conducted according to the following procedures.

- Making of route plans for the driving unit.
- Search for the image of the digital mark pattern.
- Measurement of radioactivity on unit of measurement area.
- Movement of the driving unit to next unit.
- Correction of position and posture of the driving unit.

Table I shows specification of the RAPID.

Table I. Specification of RAPID

Driving Unit		
	Mechanism	Dual-wheeled caster-drive
	Speed (cm/sec)	Max. 50
	Size (mm)	900(L) x 1,200(W) x 1,300(H)
	Weight (kg)	350
Radiation Detector		
	Type	Gas-filled detector (PR gas)
		Proportional counter
	Number of detector	16
	Sensitive window area(cm^2)	100
	Size (mm)	860(L) x 210(W) x 150(H)
	Total weight (kg)	20
Control System		
	Host computer	Pentium II processor 450MHz
	Operation control unit	Pentium III processor 500MHz
		MMX Pentium processor 266MHz

PERFORMANCE CHARACTERISTICS OF RAPID

The RAPID performance characteristics were evaluated in terms of mobility and radiation detectability. Afterwards, the RAPID was applied to the actual measurement in the radioisotope production facilities (RIPF) in JAERI. The outline and the results of the tests and the actual measurement are described as follows.

Mobility and Detectability

The RAPID was tested for confirming positioning accuracy. The positioning accuracy was determined by running in two combinational rectangular regions. The orbital errors of the RAPID in transverse directions were measured when the self-position identification process was active or inactive. In addition, radioactivity on concrete surface of $12m^2$ area (2.5m x 4.7m) was measured with the RAPID to evaluate its efficiency. Three standard sources (intensity: ^{60}Co

70Bq, size: 1cm x 1cm) were installed on this area. External radiation source (intensity: ^{60}Co 175kBq, diameter: 1mm, dose rate: 100micro Gy/h) was installed in the vicinity of the measurement area. The host computer of the RAPID divided the measurement area into unit of 66, and made route plans for the driving unit. The RAPID was moved in the direction of X axis 22 times, and moved in the direction of Y axis twice to measure the area. The accuracy of the orbit could be maintained while the RAPID moved at the mobility performance test.

The following results were obtained in the test. Figure 3 shows results of the measurement. It was found that the detection limit for ^{60}Co was about 0.14 Bq/cm^2 with 30 seconds of measurement time. The RAPID has a capability to measure contamination distribution automatically with 12 m^2/h in efficiency.

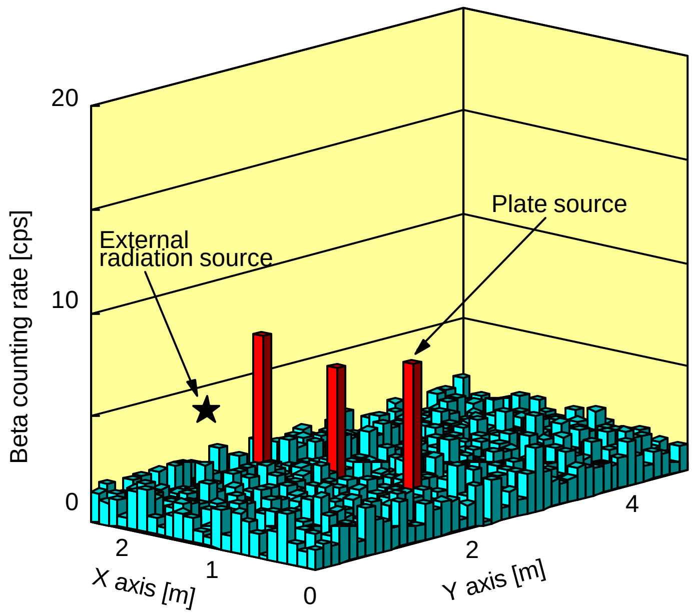

Fig. 3. Results of measurement (beta counting rate)

Application

The RAPID was applied to the measurement of radioactivity on the floor of corridor in RIPF. Shape of the floor on corridor is rectangle. Size of the floor was 2.3m width and 100m length. Area of the floor was approximately 120m^2. The actual measurement divided the floor on corridor into approximately 40 blocks. The host computer of the RAPID divided each block into the unit of 66. It took 24 hours to measure the floor on corridor.

The following results were obtained through the actual measurement. Measurement efficiency was 5m^2/h. It took 16 hours for preparation and clean-up work. The manpower expenditure was 16 man-days during the actual measurement in RIPF. The work efficiency was therefore evaluated to be approximately 7.5 m^2/man-day including the preparation and clean-up work. The measurement efficiency was approximately a half at the performance test. However, much time was necessary for measurement to avoid the obstacles in case that there were fireplugs in the planed route. Figure 4 shows measurement activities using RAPID in RIPF.

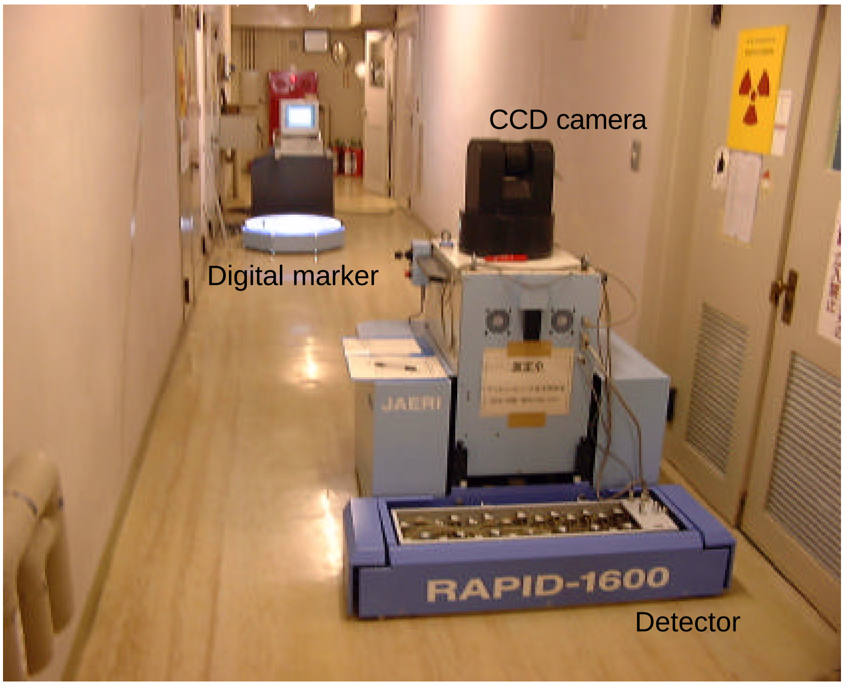

Fig.4. Measurement activities using the RAPID

CONCLUSION

On the bases of lessons learned in the JPDR final radiation survey, the new radiation measurement device (RAPID) was developed for application to radiological characterization and final radiation survey in decommissioning.

The RAPID has a capability; 0.14 Bq/cm^2 of detection limit for ^{60}Co, in 30 seconds of measurement time. It was applied to the actual measurement in RIPF in JAERI and its efficiency was evaluated to be 5 m^2/h, which is two times faster than conventional handy-type detector. The RAPID was expected to be a useful tool for measurement of radioactivity in decommissioning nuclear facilities.

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REFERENCE

1. M. Tachibana, et al., "Procedure for segregation of non-radioactive waste related to decommissioning nuclear facilities, experiences on the Japan Power Demonstration Reactor Dismantling", J. At. Energy Soc. Japan, 41(6), 677(1999).
2. M. Hatakeyama, et al., "Decontamination and radioactivity measurement on building surfaces related dismantling of Japan Power Demonstration Reactor (JPDR)", JAERI-Tech 97-064(1997).
3. S. Yanagihara, et al., "Decommissioning and decontamination programs in the Japan Atomic Energy Research Institute", Proc. IMech E 1998, C539/22, London(1998).
4. S. Yanagihara, M. Hatakeyama, H. Itoh, et al., "Mobile robot with a self-positioning system",

Advanced Robotics, 15(3), 293(2001).
5. M. Hatakeyama, et al., "Development of building surfaces contamination measurement technique", JAERI-Tech 2000-056(2000).