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A System Design for The Tomographical Assay

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Abstract

A remote operational system for the tomographical assay was designed to scan the sample and to assay the inside radioactive materials distribution three dimensionally, composed of 3 axes moving table, collimator, data acquisition system in a PC control. The system design was done by considering that how the accurate assay be affected by the modeling or by the other system components. In the system design, MCNP code simulation was done to find the optimum condition for the spatial assay of the radioactive materials.

1. Introduction

The tomographical assay system was designed to simulate the spatial burnup distribution, the detection sensitivity of the replaced dummy rods in the assembly for the safeguards and the inhomogeneity of the radioactive materials in the matrics by detecting the gamma rays. A gamma rays method is generally used to assay the nuclear materials under the assumption of homogeneous medium. However, the nuclear materials are not actually distributed homogeneously in the matrics. Therefore, the effect caused by the inhomogeneous must be considered to get the accurate assay. Tomography is an only way to assay the spatially distributed radioactive materials. However, there are many restrictions on the assay of the actual spent fuels because many intense gamma rays are emitted in the broad energy range from the produced radioactive materials. Therefore, the well confined energy selected gamma rays should be properly used to analyze the spent fuels nondestructively.

MCNP[1] code simulation was done on the detection sensitivity from the source positions and the detection interference from the adjacent at the actual measurement. In the sensitivity simulation, the cesium-137 was inserted into the manufactured 7 by 7 cell geometry and the characteristic gamma rays from the cesium-137 was used to assay the spatial distribution in the designed system. Therefore, the objective of the work is to find the optimum condition for the measurement and to examine how sensitively spatial assay can be simulated in the 7 by 7 geometry by measuring the gamma rays emitted by the cesium on the designed system with the proper resolution.

2. System Design

The assay device was designed for the tomography by considering that how the accurate assay could be affected by the modeling or by the other system components[2]. The major technology of the tomography was 1)the designed system control, 2)the data acquisition, 3)the reconstruction from the projected data. The designed assay system consists of the remotely controlable three axes moving table, two layer collimator, data acquisition system, and the control software. The three axes moving table was designed to operate the object along the X, Z axis and to rotate in θ degree with the resoution of 0.0125mm basic pitch distance and 0.1 degree rotation to detect the emitted gamma rays per projection. The encoder was used to compose of a closed loop of the control to increase the accuracy of the moving distance. The two layers lead was designed to confine the direction of the incident gamma rays and the directioned unscattered gamma rays were detected at NaI(Tl) detector. Each layer of the lead collimator has two blocks which move in the opposite

Table 1. Detection contribution from each center cell : 0^0 rotation (4X4mm collimator hole size)

Center cell No	Normalized photon intensity at NaI detector	
	650keV - 670keV	Total energy range
1	1.07173E-6	1.56050E-6
2	1.32376E-6	2.16809E-6
3	2.33571E-6	3.07234E-6
4	2.99841E-6	4.47736E-6
5	4.47790E-6	6.52227E-6
6	5.80182E-6	9.22983E-6
7	9.86742E-6	1.52801E-5

direction on the axis and one layer is rotated by 90 degree to another. Therefore, the created center hole by the two layers can be used for the directional gamma rays measurement and the hole can be adjusted for the experiment. From the code simulation, unscattered gamma rays, penetrating lead, had an one hundred times less sensitivity at 20mm thickness.

As shown at Fig. 1, the moving table and the collimator were connected with the motor driver unit and NaI(Tl) detector was directly controled by the main computer. Therefore, the control system installed at PC could manage from the directional detection per projection to the data analysis.

3. Detection Sensitivity Simulation using MCNP Code

A typical 7 by 7 cell having 19mm pitch and 10mm diameter hole size was constructed to simulate fuel rods as shown in Fig. 2. Cesium-137 was inserted into the 7 by 7 cell geometry, which was usually used in the analysis of spent fuel burnup nondestructively. To find the optimum condition for the measurement in the designed device, the detection probability through the collimation was calculated from the each source cell position and the adjacent cells of the collimated due to the sample rotation. From the code simulation, the detection probability from the cell number 7 was 10 times greater than that of cell number 1 at the 8X7mm collimator hole size and at the 4X4mm collimator hole, the detection contribution from each cell was about 3 times less than that of 8X7mm size. In the detection interference simulation, the detection probability was contributed to 5mm above the collimated line at 4X4mm size and above 5mm, the probability was about 150 times less sensitive than that of 1mm above. Therefore, the detection interference from the uncollimated cells must be considered to increase the assay accuracy. Table I represents the detection contribution from the each cell position in the 0 degree rotation at the 4X4mm collimator size.

4. Result and Conclusion

The system, having enough spatial resolution, was designed and made it possible to assay the spatial distribution of the radioactive materials from the detection of the gamma rays per projection. The control system could manage from the sample moving to the data acquisition on a PC screen. From the code simulation, the selected lead collimator was enough to discriminate the scattered gammas as a noise and the proper collimator hole size was decided by the simulation of the detection probability. This simulation gives an information for the reduction of the detection interference from the unwanted signals in the actual detector measurement.

References

1. Judith F. Briesmeister, MCNP-A General Monte Carlo Code for Neutron and Photon Transport, LA-7396-M, Los Alamos National Laboratory, 1986.
2. Yong-Deok Lee, ``Tomographical Technology Development For Nuclear Material Assay'', KAERI/RR-1570/95.

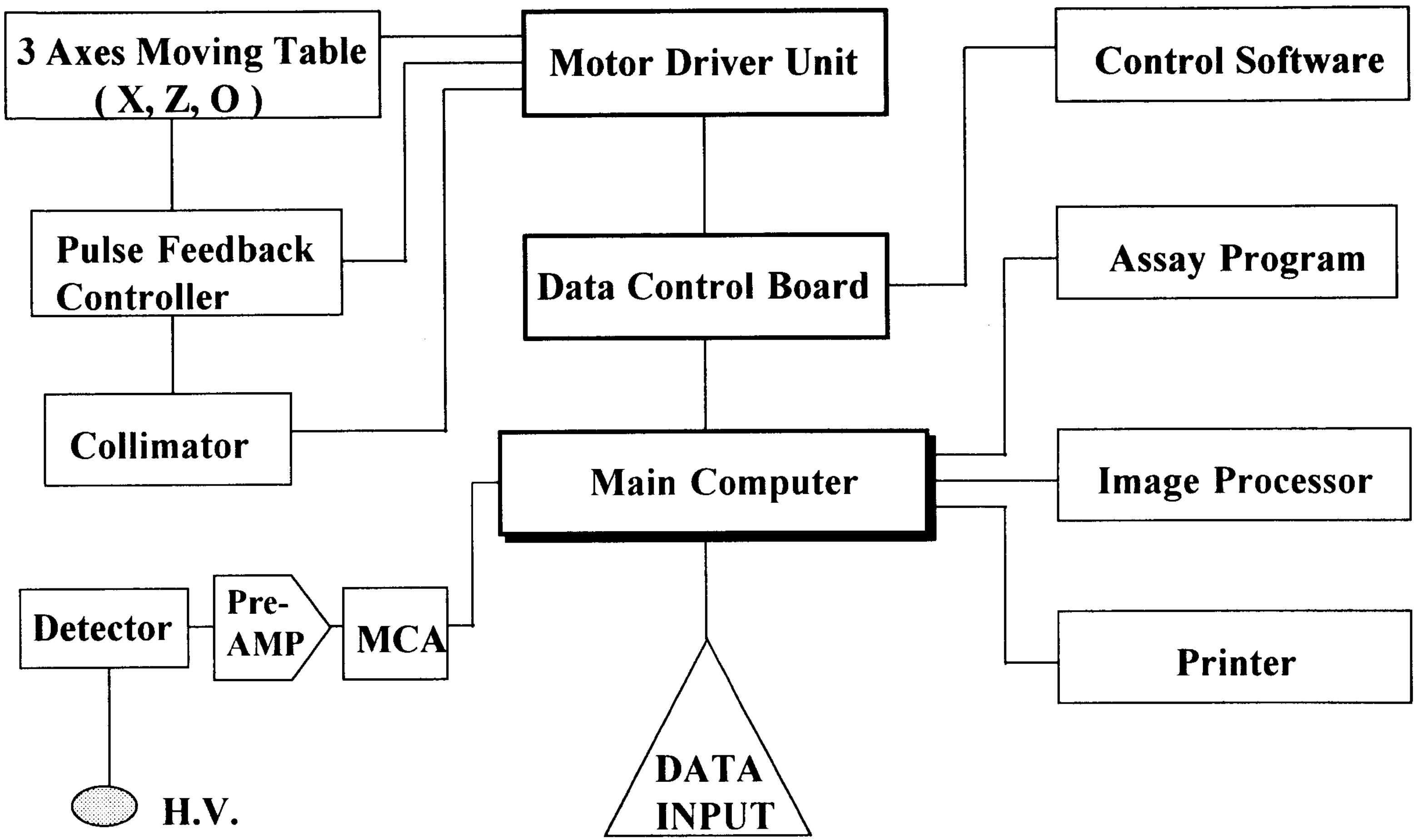

Fig. 1. A block diagram of the tomographic assay system.

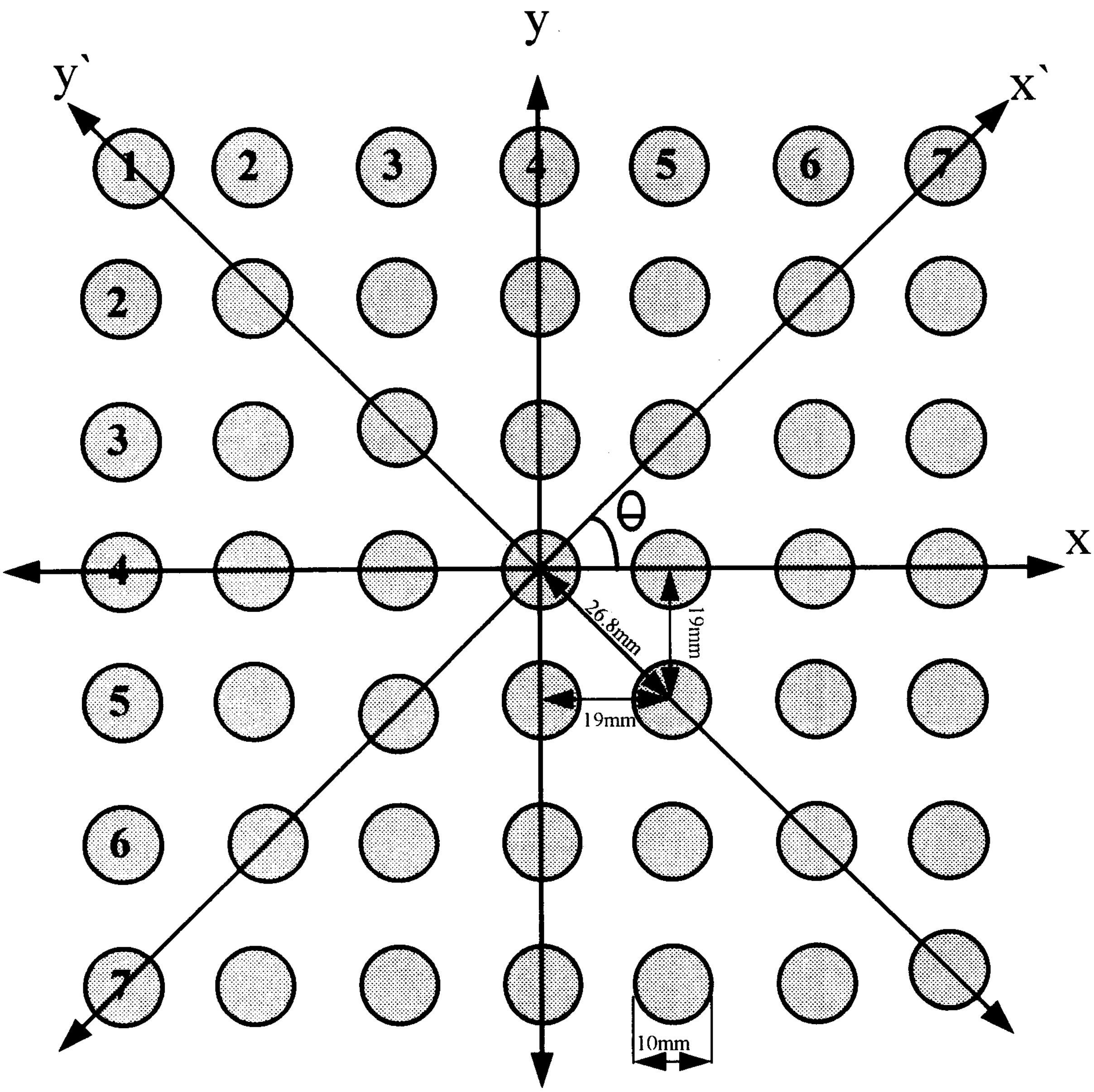

Fig. 2. Sample geometry configuration (7X7).