Development of an Industrial SPECT to Study Dynamic Behavior of Plant Process Flow

Jang Guen Park [a], Chul Hee Min [a], Chan Hyeong Kim [a,*], Jong Bum Kim [b], Sung Hee Jung [b]
[a] Department of Nuclear Engineering, Hanyang University, 17 Haedang-dong, Seongdong-gu, Seoul, 133-791, Korea
[b] *Korea Atomic Energy Research Institute, Dukjin-dong, Yuseong-gu, Daejon, Korea, 305-353*
[*] *Corresponding author: chkim@hanyang.ac.kr*

1. Introduction

Radioisotope technologies are currently widely used to investigate the spatial distribution, flow pattern, and mixing characteristics of process media [1]. It is still, however, a great challenge to obtain a satisfactory result for a multiphase flow that can be easily found in a refinery, petrochemical plant. The radioactive particle tracking (RPT) technique [2] was recently proposed as a promising method, which can, however, supply only very limited information on the flow dynamics.

Legoupil et al. developed an industrial single photon emission computed tomography (SPECT) and applied it to visualizing the flow dynamics of a process system. The industrial SPECT allows a real-time analysis of flow distribution based on the distribution of radioactive tracer injected in the system [3,4].

In the present study, several different geometries of the industrial SPECT were evaluated for imaging a lab-scale flow system by the Monte Carlo method [5], in terms of imaging quality for a ^{99m}Tc gamma radiation source. Based on the test results, an optimal geometry of the imaging system was determined for imaging the lab-scale flow system.

2. Methods and Results

To determine the optimal design of the industrial SPECT for a lab-scale flow system, the present study modeled a point source of ^{99m}Tc located in a cylindrical basin (ϕ =30 cm, filled with water) and NaI(Tl) detectors mounted in array (ϕ =1.3 cm, h=2.5 cm) using the MCNPX code. Monte Carlo simulations were carried out changing several parameters: (1) the detector arrangement, (2) the diameter of the collimation apertures, and (3) the object-detector distance. The images of the industrial SPECT were reconstructed by using the Expectation Maximization (EM) algorithm [6].

2.1 Detector Arrangement

To evaluate the influence of detection arrangement on the imaging quality of the industrial SPECT, a point source of ^{99m}Tc at 5 cm away from the center of the cylinder was simulated with 24 detectors installed in square and hexagonal geometries as illustrated in Fig. 1. The reconstructed image from the hexagonal arrangement shows a clear spot at the position of the source, while the image by the square arrangement shows a blurred spot near the position of the source with two additional spots (Fig. 2).

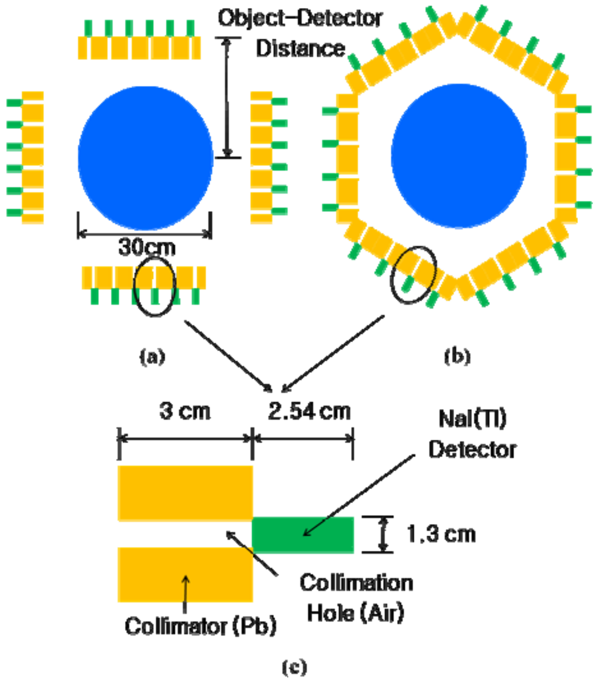

Fig. 1. Square and hexagonal arrangement of the detectors (a, b) and the geometry of radiation detector, collimation (c) as modeled in the MCNPX code

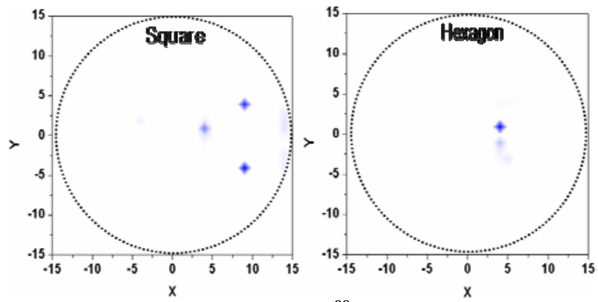

Fig. 2. Reconstructed images of a ^{99m}Tc point source for different detector arrangement

2.2 Diameter of Collimation Aperture

The diameter of the collimation aperture affects both the imaging quality and the counting efficiency; that is a detector with a small collimation aperture will focus on a specific area for better imaging resolution, but it will compromise the statistics of radiation counting.

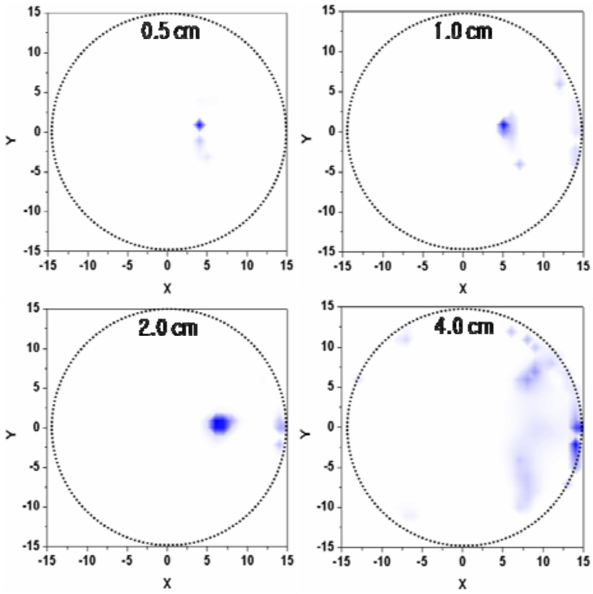

Fig. 3. Reconstructed images of a ^{99m}Tc point source for different collimation diameters

Fig. 3 shows the reconstructed images with the collimation aperture of 0.5, 1, 2, and 4 cm in diameter, respectively. The radiation source locations in the images of 2 cm and 4 cm are not correct and significantly blurred. The sources are well identified in 0.5 cm as well as in 1 cm. A detector with 1 cm aperture, however, would be advantageous over 0.5 cm aperture in the statistical point of view.

2.3 Object-Detector Distance

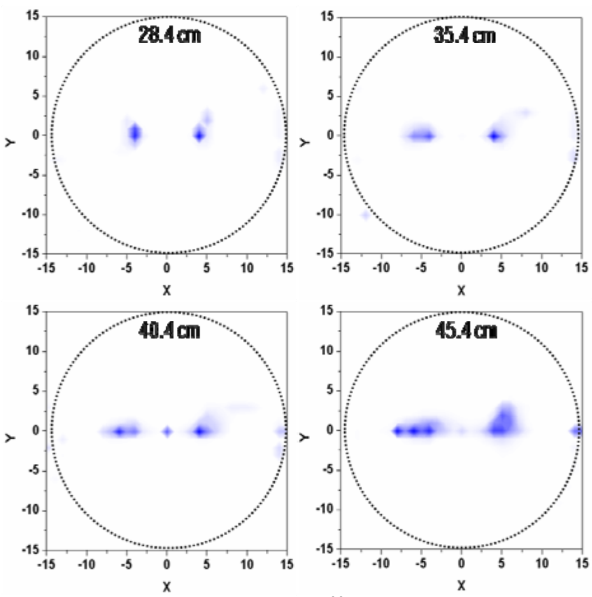

Fig. 4. Reconstructed images of a ^{99m}Tc point source for different object-detector distances

The distance from the center of the object to the frontal surface of a detector is another important factor which could affect on the imaging quality. Two ^{99m}Tc sources at 5 cm away from the center in the opposite direction were simulated with the object-detector distances of 28.4, 35.4, 40.4, and 45.4 cm. It is obvious from Fig. 4 that the source spots get blurred more along with the increased distance.

3. Conclusions

This study was to determine an optimal design of an industrial SPECT. Our results show that the hexagonal arrangement of the detectors with 1 cm diameter collimation and 28.4 cm object-detector distance is an optimal configuration of the industrial SPECT at least for a cylindrical object of 30 cm diameter. The optimal design determined from the present study will be used for the construction of a lab-scale industrial SPECT at Korea Atomic Energy Research Institute (KAERI).

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