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Neutron tomography of two different internal structures in cask storage

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Dry storage facilities necessitate a reliable safeguards technique which is able to detect any undeclared activities such as diversion, misuse, or theft of spent nuclear fuel assemblies in a cask. Many techniques based on gamma, neutron, or muon have been applied but suffered from low accuracy caused by shields of a cask. Therefore, the present authors developed a new tomography system employing new He-4 gas scintillation detectors, designed to simultaneously measure both thermal and fast neutrons without any moderators.
To demonstrate the availability of the experimental system, Monte Carlo simulation has been first carried out regarding the actual cask dimension(HI-STAR) and material information of spent nuclear fuel. 19 detectors were linearly arrayed and positioned at the middle of a cask. 36 image profiles were obtained at every 10 degrees and aligned in single frame image called a sonogram. The cross-sectional image was then fabricated by the inverse radon transform algorithm.
In this study, two cases of the spent-fuel diversion were considered. The first case is that the spent fuel is removed from the cask and then the lid is closed. The second case is the same as the first case but empty spaces are filled with the dummy fuels composed of high-Z number non-radioactive materials (dummy fuel). As shown in figure, five different diversion scenarios were considered for each case in order to check the change of spatial resolution of the cross-sectional image.
It was resulted that the new tomography system can detect a possible partial or gross defect of assemblies for both cases, but also pointed out that it depends on the position where diverted assemblies were previously located. Defining diversion of some central assemblies is notoriously difficult with neutron tomography since the quality of cross-sectional images is dominated by neutron information mostly emitted by the close spent fuel assembly.
This study showed that the new neutron tomographic system has considerable potential to detect some nuclear fuel diversion. Future steps will be to experimentally demonstrate the actual system with some nuclear materials and conduct various parametric studies to enhance the image quality.

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