Safeguards Verification for CANDU Spent Fuel Stored in the Pond Using Optic Detector

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1. Introduction

For safeguarding, CANDU spent fuels in the storage pond of Wolsong nuclear power plants have been verified by the current equipment, which measures gamma ray from the spent fuel[1]. Unfortunately, there are so installed funnels on the bottom plate of the pond that the equipment can't verify them, i.e., the bundles around the funnels. Currently, as safeguards verification method for them, the trays containing the spent fuel bundles are moved for providing a witness of the international atomic energy agency (IAEA) inspector. This movement has given a burden to the facility due to safety reason. To solve this issue, development of new equipment without the movement of the trays has been initiated between Korea and the IAEA. Thus, optic detector has been developed for the safeguards verification of the spent fuel stored in the pond of Wolsong. The results of the field verification are presented.

2. Optic Detector

In theory, thermal neutrons incident on the optic detector induce a ^{6}Li(n,α)^{3}H reaction with 4.78 MeV of exothermic energy mostly carried by the ^{3}H. When the ionization by the alpha particle and ^{3}H transfers energy to Ce^{+3} ion, the emission of optical photons creates during the return to ground state. And also the glass in the optic detector is sensitive to gamma rays that interact by photoelectric absorption, Compton scattering and pair production[2,3].

The optic detector, which is made of cerium-activated lithium-silicate glass, has been developed due to self-power and small size available, especially, applying without a preamplifier at measurement position of radioactive materials as using a light guide. Thus, because of this advantage, this the light guide available[4] commercially was used to transmit the fluorescence light, 375 to 420 nm of wavelength, when an interaction with the scintillating material in the optic detector occurs and the light is sent to a PMT through itself as shown Figure 1. Even though the light loss is known for approximately 150 dB per kilometer at the wavelength, 400 nm, it can be ignored in this application using several meters.

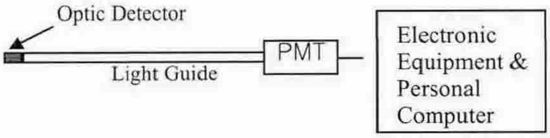


Figure 1. Layout of optic detector for verification of CANDU spent fuel

3. Results and Considerations

First of all, it has been considered that the only way to reach the bundles placed at around funnels is by inserting the optic detector with collimator into the narrow space between the bundles, not between the stacks because of the funnels. This inserting way creates a stress because an effective radiation shield against the very strong radiation from the spent fuels is likely to be difficult. Thus, the optic detector with a light guide is required for the test on a durability and linearity against high radiation intensity. For the durability test, the optic detector with the light guide were irradiated up to accumulated dose 10^7 at dose rate 10^4 of ^{60}Co. The results showed that the measured signal kept its value constantly during the exposure period without any damage. The result for the linearity from 500 rad/h to 5,000 rad/h was evaluated within 4.3%. To know how many contribute gamma ray to the light guide, the light guide was also irradiated. The contribution was about 9.8 percent per meter comparing with 5 mm in length by 1 mm in diameter, actual the optic detector size. Until now, the results of the test have shown that the optic detector can be applied for the verification of the spent fuels.

Thus, the optic detector was mounted in a collimator, which is made a lead of 1cm(thickness) by100 (width) by 150 cm(length) and has a hole for a beam collimation at the optic detector position. A field test was done at Wolsong unit 3. The results showed that the optic detector measured the peaks corresponding to an individual bundle, i.e., verifying the number of spent fuel bundles by item counting in safeguards, as shown in Figure 2. The signal level increased along with the scanning from the top to the bottom plate located the funnel. It was attributed to the light guide. Actually, the straight line is by the light guide. The amplitudes of the peaks appeared differently. So, the burn-up and cooling time were investigated to establish whether they are related to the peaks' amplitude, or not. It was confirmed that it depended on most likely on the burn-up, i.e., burn-up is high then the amplitude is big, while a low burn-up has small amplitude. The optic detector also measured the bundles during a downward and upward scanning. The result showed a remarkable symmetry as shown in Figure 3. Left part on the center is the downward scan and the other is the upward scan. The tests were performed several times at other spots in the pond. The results showed the same symmetry in shape and the same number of peaks.

4. Conclusion

The optic detector proved for its durability against high radiation intensity. Although the signal by the light guide was contributed to that of the optic detector, it hasn't effect on measuring the peaks, i.e., the verification by item counting of the spent fuel bundles was possible. Thus, the results of the field tests verified the bundles placed at around funnels of the stacked spent fuels. The optic detector will be demonstrated in the real field according to an action plan between the IAEA and Korea. If the optic detector is certified by the IAEA, the current verification by the movement of the trays will be not required. And also we can expect a cost reduction because the optic detector is cheaper than the detector of the current equipment.

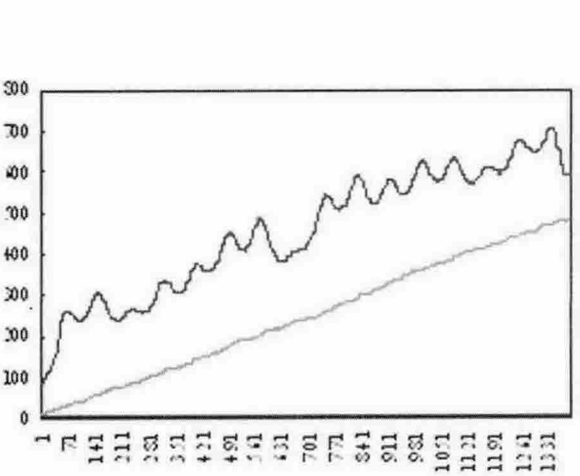
Reference

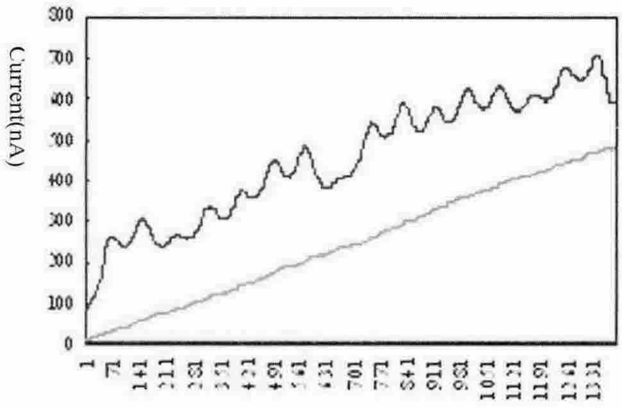
[1] IAEA, "Safeguards Criteria" 1998 edition.

[2] J. S. Kim, et at., "Application of Optical Fiber Scintillator for Unattended Monitoring in Spent Fuel Storage Silo," INMM 41st Annual Meeting, 2000.

[3] M. Bliss, R. A. Craig, D. S. Sunberg, and W. Sliger, "Glass-fiber-based Neutron Detectors for High and Low Flux Environments," SPIE, 2551, pp108-117, 1994.

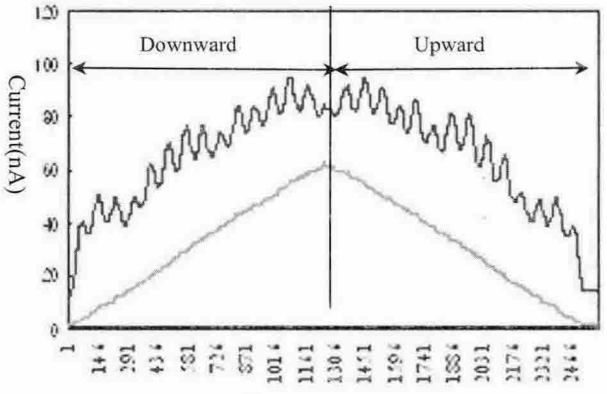
[4] Thorlabs Inc. Catalogue 1998 ; Section III-Fiber Optics (http://www.thorlabs.com)





Time (second)

Figure 2.. Measured peaks corresponding to individual spent fuels



Time (second)

Figure 3. Measured results for downward And upward scanning