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Sensitivity Measurement of a long SPND by a Split Neutron Irradiation

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1. Introduction

A Self Powered neutron Detector (SPND) has been used effectively as an in-core neutron monitor for a long time both in nuclear research reactors and power reactors due to its very simple dimensions and structures. For power reactor applications, Rhodium, Vanadium, Platinum, and Silver are usually used as the typical emitter materials for the SPNDs. The SPNDs with a Rhodium emitter (Rh-SPNDs) are most frequently used at Korean Standard Nuclear Power stations (KSNP) as a fixed in-core neutron detector. This paper describes a new method to measure the neutron sensitivity of the Rh-SPNDs with a long sensitive length at a horizontal beam tube of HANARO by a split irradiation of them.

2. Characteristics of Rh-SPNDs

2.1 General [1]

Rh-SPND composes of a rhodium wire as an inner electrode (emitter) surrounded by Al_2O_3 insulator and an outer inconel sheath (collector). Typically Rhodium wire has a diameter of 0.045 cm and a length of 40 cm. The diameter and total length of Rh-SPND used at KSNP are 0.16 cm and around 40 m respectively. Rhodium has a relatively high cross section to thermal neutrons and produces delayed beta particles (electrons) through β^- decay after the (n,g) reaction. The sensitivity of a SPND is defined as a total output current divided by a total neuron flux. The theoretical sensitivity of Rh-SPNDs is around 4.0×10^{-20} A/nv.

2.1 Sensitivity measurement

The neutron sensitivity of SPNDs can be measured by an absolute or comparative method. The absolute method involves exposing the SPND to a neutron field and measuring the output current. Neutron flux during an exposure is determined from an activation analysis by using activation foils (or wires) with high purities and well-known cross sections such as Cobalt or Gold. Then the sensitivity is readily calculated through a measured output current divided by a measured neutron flux.

To measure the sensitivity comparatively, a standard SPND with a known absolute sensitivity and physical characteristics identical to the test SPND is needed. After an irradiation of them together or separately under the same circumstances, the sensitivity is readily calculated by comparing the output current of the test SPND to that of the standard SPND.

While the sensitivity may be measured at the installation site or in a research reactor prior to a final installation, the SPNDs for the power reactor applications are usually measure for their sensitivities by using a research reactor.

3. Measurements and Results

2.1 Site preparation

When the sensitivity measurements of SPNDs are performed by using research reactors, the proper neutron flux level is in the order of 10^9 n/ cm^2-sec in general. It is because the experiments can be performed easily and accurately by reducing the amount of neutron activation of the SPNDs as well as the activation foils.

The experiments to measure the sensitivity of the Rh-SPNDs for the power reactors were carried out at the Ex-core Neutron Facility (ENF). ENF is one of a seven horizontal neutron beam tubes of HANARO and it was modified for the Boron Neutron Capture Therapy (BNCT) in 2001 [2]. It can provide almost a pure thermal neutron beam ($R_{cd} > 80$) with a high density (~ 2×10^9 n/ cm^2-sec) by minimizing the gamma radiation. In addition, the wide and clean experimental space of the ENF is able to accommodate various auxiliary tools for the experiments.

2.2 Devices for split irradiation

Because the effective beam size of the ENF is around 15 cm in diameter, it is not enough to cover the whole sensitive portion of Rh-SPNDs. A method where the SPNDs are irradiated in several sections was considered. For a split irradiation, neutrons should be exposed to the only selected part of the SPNDs. And the SPNDs should be moved to the preset positions correctly to be irradiated in order to avoid on overlap in successive sections.

A beam collimator with an adjustable neutron shielding door against the neutrons was developed. The shielding door is composed of a couple of boron contented plastics of 2 mm thick and a high purity cadmium plate of 1 mm thick. Figure 1 shows the shielding effect calculated by the MCNP computer code. In a practical measurement by using activation foils and Rh-SPND, it was confirmed that the shielding door is able to protect the thermal neutrons effectively without any contribution to the generation of an output current. The width of the neutron beam was selected as 10.5 cm by considering the splitting of SPND into four sections and a uncertainty in the length of the Rhodium emitter.

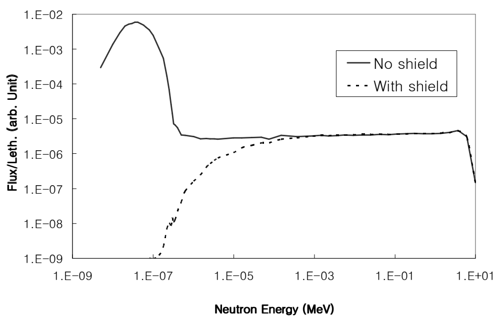

Figure 1. The shielding effect estimated by MCNP

A movable bed to hold the SPNDs was manufactured and assembled with the beam collimator. We can also load activation wires to measure the neutron flux during an irradiation. The shielding window and moving bed is controlled by a computer system located outside the ENF room.

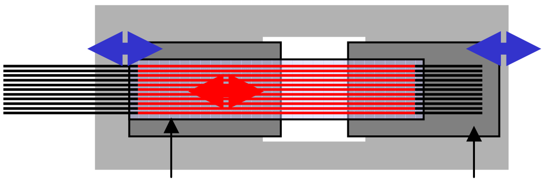

Figure 2. A conceptual sketch of split irradiation device

2.3 Measurements

Four Rh-SPNDs, which have the same physical characteristics with the commercially used ones at KSNPs, were tested at the ENF of HANARO. They were irradiated in a position for about 10 minutes to measure the saturated output current generated within a section of the detectors, and then moved to the next position. Such a partial measurement was repeated until all the sensitive parts were completed. Finally the total output current from each Rh-SPND was obtained by a summation of all the partially measured results.

At the last section of the SPNDs, a gold wire of 10 cm long was attached near to every Rh-SPNDs in order to measure the neutron flux during an irradiation. The absolute or relative neutron flux at each position was calculated from the measured activities of the gold wires using a gamma spectrometry system [3]. Absolute neutron sensitivity of the Rh-SPNDs was determined by dividing the total measured current by the absolutely measured neutron flux and they were compared with the original values supplied from the manufacturer. The test results at the ENF Facility are summarized in table 1.

Table 1. Measured results

	Measured sensitivity ($x10^{-20}$)			Reference value
	1st	2nd	3th	
SPND-1	3.853	3.850	3.852	3.9068
SPND-2	3.851	3.847	3.849	3.8901
SPND-3	3.865	3.860	3.849	3.9038
SPND-4	3.863	3.851	3.863	3.8806

4. Conclusion

The measurements of the neutron sensitivity for the Rh-SPNDs with a long effective length were carried out at the ENF of HANARO. Due to the limited neutron beam of the facility, a device composed of a width controllable beam collimator and a transferring bed for the Rh-SPNDs was developed so as to accommodate up to 11 Rh-SPNDs simultaneously and to measure their sensitivities in an absolute and/or a comparative way. Commercially used Rh-SPNDs for Korean Nuclear Power Reactors were tested to verify the performance of the developed method. And it was confirmed that neutron sensitivity of Rh-SPND with a 40 cm length can be measured precisely by irradiating them in sections using a narrow beam tube of HANARO. A good reappearance in the repeated measurements of each SPND was also obtained.

REFERENCES

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