Status of Vanadium Self-Powered Neutron Detector Depletion Test

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1. Introduction

Self-Powered Neutron Detector (SPND) has been commonly used in commercial nuclear power plant for measuring the neutron flux as an input signal for core monitoring system. KHNP CRI has the plan to conduct SPND depletion test at HANARO for development of Long-lived In-Core Instrument (LLICI) assembly. The depletion characteristics of several types of SPNDs including Vanadium SPNDs will be verified by depletion test at HANARO. The capsule, junction box and data acquisition system (DAS) were designed for initial sensitivity measurement, depletion characteristics and the dynamic compensation constant measurement of Vanadium, Rhodium and Cobalt, and installed in HANARO. Before the HANARO operation, pre-test for DAS has been successfully completed.

2. Preparation of depletion test

In this section, SPND capsule and data acquisition system for SPND depletion test are described. The objective of the test is to measure the SPND signals and make the parameters necessary for nuclear design and core monitoring. The following are main parameters for SPND characteristics that can be obtained by measurement.

- Initial Sensitivity
- Dynamic compensation constant
- Depletion constant

2.1 Capsule Design for SPNDs

The SPND consists of emitter, insulator and collector. The volume of the emitter affects the magnitude of the signal. Through SPND performance test [1], the detailed design was finalized by increasing the diameter of vanadium emitter.

The SPND capsule consists of 5 Vanadium (V) SPND, 7 Rhodium (Rh) SPND, 2 Cobalt (Co) SPNDs and 3 background cables. The following are considered for SPND positions in the capsule.

- Comparison of SPND signal (V, Rh and Co)
- Characteristics of background detector signal
- Interference of SPND signals

Finally, the positions of SPNDs inside capsule minimized the signal interference of each emitter materials (V, Rh and Co). The SPND capsule for depletion test will be loaded in OR irradiation hole. Figure 1 shows OR irradiation hole location in top view of HANARO core. The Lower left hole outside of core will be used for the depletion test (Fig. 1).

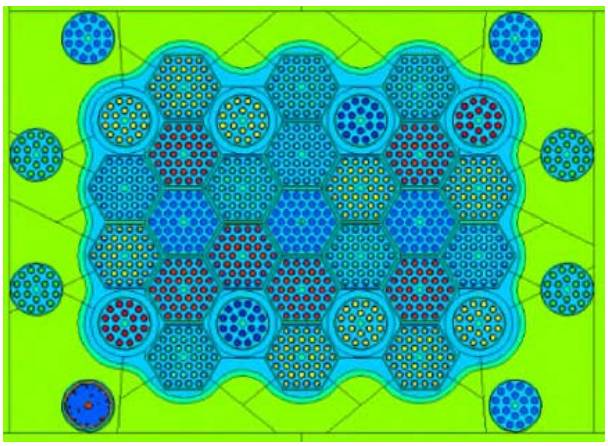

Fig. 1 Configuration of OR irradiation hole in HANARO

2.2 Data Acquisition System

Data Acquisition System (DAS) is an equipment to measure raw current signals of SPNDs and to separate the noise. DAS consists of I/V converter module (IVCM), Advant Controller 160 Programmable logic Controller (AC 160 PLC) and Data Acquisition (DAQ). Raw current signal of SPND is stored in database through DAS. Figure 2 shows the configuration of signal processing procedure.

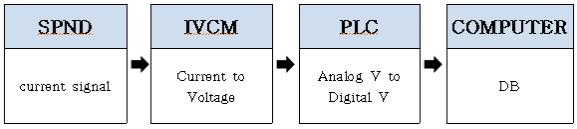

Fig. 2 SPND signal processing procedure of DAS

3. Inspection of test equipment

3.1 Signal Acquisition Path

For SPND depletion test at HANARO, KHNP CRI & KAERI completed installation of SPND signal data

acquisition system. It consists of SPND capsule, Junction box, DAS and data acquisition computer. Figure 3 shows overview of SPND signal acquisition system. Each of SPND signal and Core operation information are transferred to data acquisition computer.

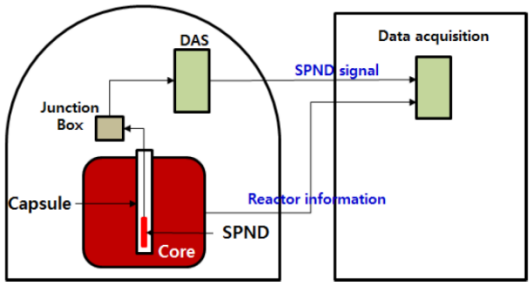

Fig. 3 Overview of SPND signal acquisition system

3.2 DAS installation test

In general, DAS may experience performance changes due to unforeseen changes in the installation process. And raw current signal of Vanadium SPND is expected to be smaller than Rh SPND raw current signal. Therefore, it is necessary to check the input signal range of DAS after installation. The objective of simulated signal acquisition test is to identify reliable input signal range of DAS after installation at HANARO. The signal input range of simulated signal test can be covered from 10 nA to 10 μA.

DAS has four channels that can be measured simultaneously. Table 1 shows the measured results on some channels. The simulated signal test result has shown that the same DAS performance will be expected during the depletion test.

Table 1: Result of simulated signal acquisition test

CH	Simulated Signal	Prediction Data (V)	Acquisition Data (V)	Error (%)
01	500 nA	0.5	0.499	0.20
	1 μA	1	0.996	0.40
	5 μA	5	4.969	0.62
	10 μA	10	9.940	0.60
04	500 nA	0.5	0.491	1.80
	1 μA	1	0.992	0.80
	5 μA	5	4.960	0.80
	10 μA	10	9.934	0.66

3.3 Monte Carlo Calculation of Initial Sensitivity

To measure initial sensitivity of SPND, emitter of SPND current signal and neutron flux at emitter location are needed (Eq.1). Neutron flux of SPND is calculated using MCNP6 code [3].

$$S = \frac{I}{\Phi} \quad (1)$$

Where S : sensitivity
I : electron current
Φ : neutron flux inside SPND

The sensitivity and depletion law (Eq.2) is presented as bellows.

$$S = S_0(1 - Q(t)/Q_\infty(t))^\alpha \quad (2)$$

Where S_0 : initial sensitivity
$Q(t)$: accumulated charges
$Q_\infty(t)$: total theoretical accumulated charges

3.4 Initial Sensitivity Measurement Process

The measurement of initial sensitivity will be conducted as following procedure.

- Real circuit noise analysis of DAS without connection to SPND capsule.
- Background noise analysis of DAS with connection to SPND capsule at Zero Power
- Data acquisition of signal from SPND(V, Rh, Co and BG)
- SPND(V, Rh and Co) Initial Sensitivity calculation

4. Summary and Future works

Several SPNDs have been successfully assembled in a capsule in HANARO for investigating the characteristics of SPND depletion and dynamic compensation. DAS has been examined through the signal acquisition path and obtained the reliable results after all installation of cables, SPNDs and relative equipment. As a result of simulated signal test, it is confirmed that as built capsule is well constructed and all equipment are installed in condition for depletion test.

The Vanadium SPND depletion test is scheduled to start from 100th cycle of HANARO. Depletion life-time, dynamic compensation constant and initial sensitivity of Vanadium SPND will be determined through SPND depletion test.

REFERENCES

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