Performance Test for Neutron Detector and Associated System using Research Reactor

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1. Introduction

The neutron detector and associated system which are used for the neutron flux and reactor power monitoring in the commercial nuclear power plant are sometimes needed to improve its performance. SPND (Self-Powered Neutron Detector) has been developed to extend its lifespan[1]. ENFMS (Ex-Core Flux Monitoring System) of pressurized water reactor has been also improved[2]. After the development and improvement, their performance must be verified under the neutron irradiation environment. We used a research reactor for the performance verification of neutron detector and associated system because the research reactor can meet the neutron flux level of commercial nuclear reactor. In this paper, we report the performance verification method and result for the SPND and ENFMS using the research reactor.

2. Research Reactor

We used UCI TRIGA reactor[3] to conduct the performance test for the SPND and ENFMS. The neutron flux of UCI TRIGA reactor was evaluated because it is main requirement for the test. Fig. 1 shows the MCNP model for the evaluation of neutron flux in this study. It is typical core model of TRIGA reactor. There are many holes in the core to accommodate the fuels, control rods and irradiating materials. Graphite reflector (green color) surrounds the core. The reactor core and graphite reflector are located in the pool.

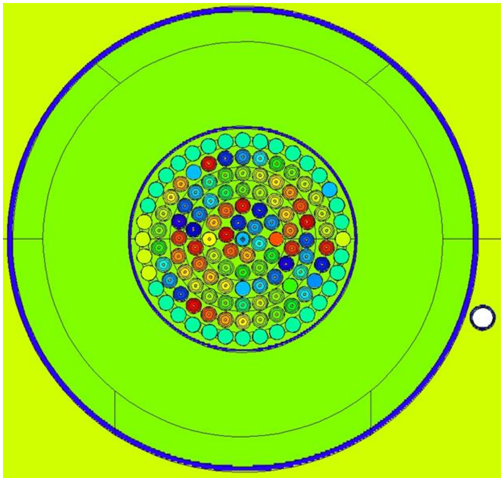

Fig. 1. MCNP model of UCI TRIGA reactor

Since the SPND is inserted in the fuel assembly at the commercial reactor, the test for the SPND is needed under high neutron flux. Therefore the central thimble hole is used for the SPND test. Its maximum thermal neutron flux by the evaluation was about $5x10^{12}$ n/cm^2-sec. To conduct the test for ENFMS, the neutron flux of wide range between 0.1 and 10^9 n/cm^2-sec is needed. Since the neutron detectors are also bigger than central thimble, the neutron detectors were installed in the outside of the core for the ENFMS test. Fig. 2 shows the result of neutron flux evaluation from the surface of graphite reflector. The maximum thermal neutron flux in the outside of reflector is enough for the test requirement.

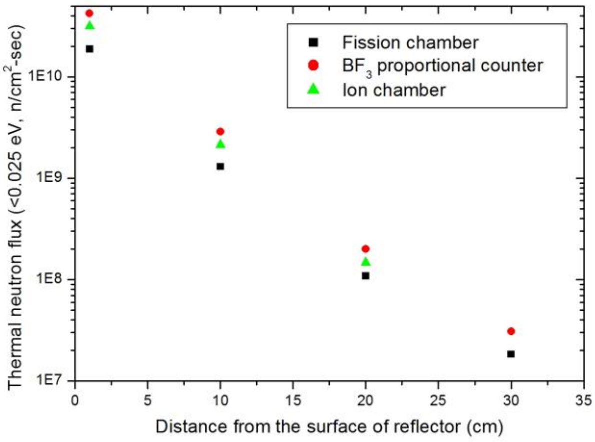

Fig. 2. The result of neutron flux evaluation from the surface of reflector of UCI TRIGA reactor

3. Test Methods and Results

2.1 SPND

KHNP designed the SPNDs for long-lived in-core instrumentation (LLICI) by changing its geometrical dimension and emitter material. Table 1 shows the SPNDs for the performance test. Total seven SPNDs and one background wire were used. Among them, Rhodium-emitter SPNDs with 1.58 mm outer diameter were used as a reference that is same with the conventional product. During the test, minimizing the difference of neutron flux is important. Therefore all SPNDs and background wire were tied by metal band with the aluminum foil and tube in the edge of emitter region as shown in Fig. 3.

Table 1. The specification of SPND for the performance test

Emitter material	Emitter length (mm)	Length (mm)	Emitter diameter (mm)/ Insulator thickness(mm)/ Outer sheath thickness(mm)	Outer diameter (mm)	Quantity (EA)
Vanadium	400	16,100	1.13 / 0.4195 / 0.43	2.829	2
Rhodium			0.46 / 0.3 / 0.26	1.58	2
Rhodium			1.13 / 0.4195 / 0.43	2.829	2
Cobalt			1.13 / 0.4195 / 0.43	2.829	1
Background wire			-	2.829	1

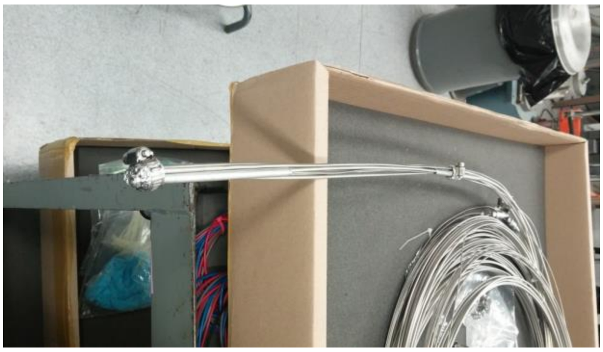

Fig. 3. The assembly of SPNDs

Fig. 4 shows the schematic diagram of the performance test for SPNDs. Assembled SPNDs and background wire were inserted into the central thimble that is dry hole for the irradiation in the center of the core. All signals of SPNDs and background wire were recorded by data acquisition system (DAS). To compare between the signals and the reactor power, the signal of compensated ionization chamber (CIC) was also recorded. The performance test has five items such as noise measurement, sensitivity, interference, linearity, and response under maneuvering reactor power.

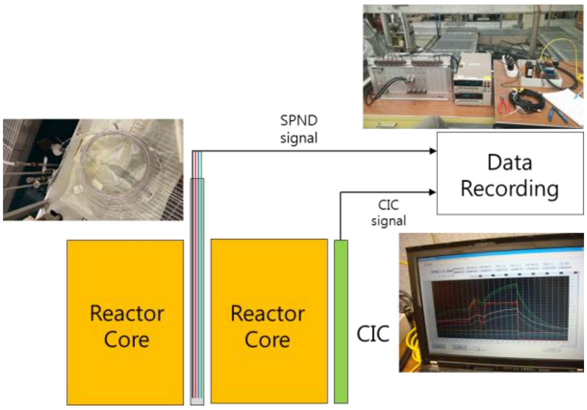

Fig. 4. The schematic diagram of the performance test

Fig. 5 shows the typical recorded CIC raw signal during the test. The abnormal signal was found in the initial reactor operation due to the electric noise from the reactor. The reactor power was initially increased and maintained at 150kW during 30 minute. And reactor power was changed to 200, 250, 200, 250, 225, 200 kW by stages. Total nine modes reactor operation was conducted for the test.

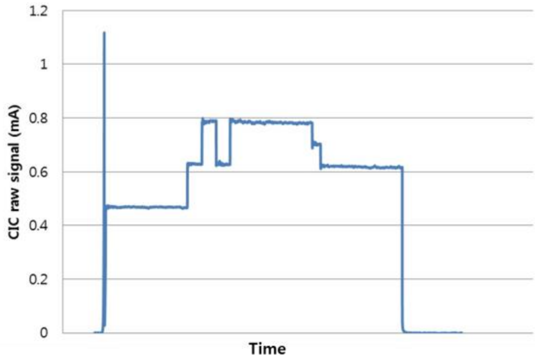

Fig. 5. The typical recorded CIC raw signal

The performance test was successfully conducted. The static and dynamic signal of SPNDs and background wire was measured and recorded by DAS. As a result of this test, we could understand the signal characteristics according to the emitter material and the size of the SPNDs and background wire.

2.2 Neutron detectors for ENFMS

Table 2 shows the neutron detectors for the ENFMS test. Three neutron detectors were used such as fission chamber, BF_3 proportional counter and ionization chamber. Since the test is conducted in the reactor pool, the test rig was designed and fabricated to prevent the contact between the detectors and reactor coolant. Fig. 6 shows the located neutron detectors in the pool for the test. Since the ion chamber was already installed in the pool, only fission chamber and BF_3 proportional counter were controlled. Their position was adjusted by the fastening device that is installed with the rack in the working area.

Table 2. The neutron detectors for the ENFMS test

Detector Type / Model	Detector dimension (diameter and length, mm)
Fission Chamber (UCI_IST NY-10382)	79.25 × 1148.08
Ion Chamber (UCI WL-8105)	88.9 × 266.7
BF3 (USERS LND 20320)	50.8 × 174.9

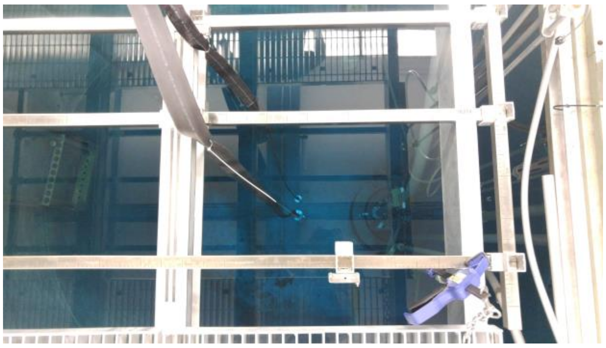

Fig. 6. Located neutron detectors for the ENFMS test

Fig. 7 and 8 show the measurement result of startup range and safety channel test of ENFMS using fission chamber and BF_3 proportional counter. The reactor power was changed tenfold. Although some measurement results are abnormal, the count rate and voltage was exponentially increased as the increase of the reactor power. Some abnormal measurements might be caused by the detector characteristic and electrical instability in the reactor hall.

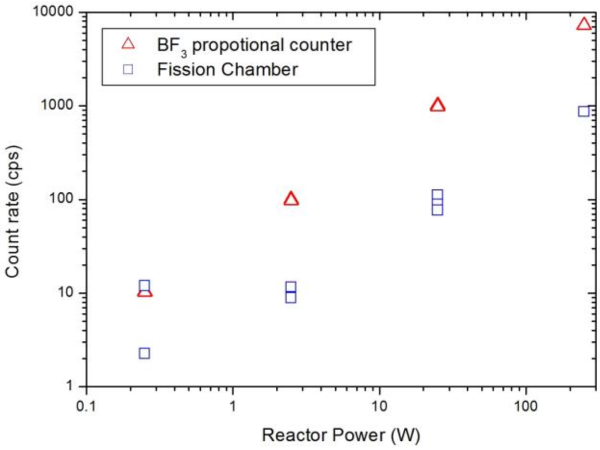

Fig. 7. The measurement result of startup range test

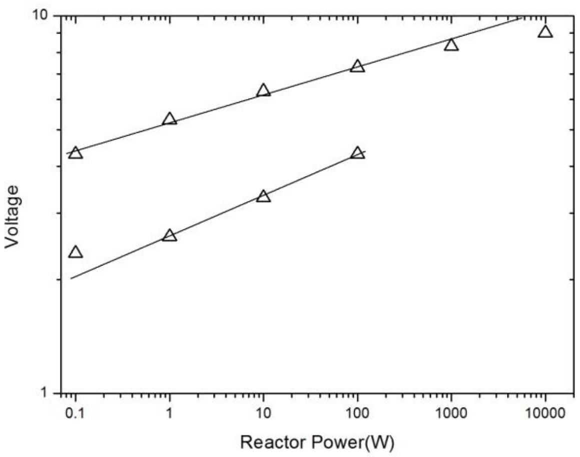

Fig. 8. The measurement result of safety channel test

The test was conducted using the converted neutron flux from the power level between 10^{-8} and 200% of commercial reactor for the improved ENFMS. Therefore the performance of tested ENFMS was verified, and thus the simulating test will be conducted using commercial reactor.

3. Conclusions

The performance tests for the SPND and ENFMS were conducted using UCI TRIGA reactor. The test environment of commercial reactor's neutron flux level must be required. However, it is difficult to perform the test in the commercial rector due to the constraint of time and space. The research reactor can be good alternative neutron source for the test of neutron detectors and associated system.

REFERENCES

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