

Signal performance comparison for background compensation wire SPND type and SPND-background detector type

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1. Introduction

As part of the i-SMR development project, ICI (In-Core Instrument) to be used in the i-SMR reactor is being developed. The types, quantities, and arrangement configuration of SPNDs (Self-Powered neutron detector) that make up the ICI were determined, and the dimensional design of SPND was carried out. The geometry and dimensions of the SPND were determined such that the magnitude of the electrical current signals generated by interactions between incident neutrons and the detector materials meets the performance requirements of the signal processing system. The magnitude of the current signal for incident neutron flux is expressed as sensitivity, and many studies have been conducted because sensitivity is an important part of SPND design. [1,2] The magnitude of the current signal is important for signal processing, but SPND background signal have large effect in accurate neutron flux calculations. The background current signal is mainly generated by (n,γ,e) , (γ,e) reaction of the SPND lead wire and sheath, and these current generated by non-neutron reaction acts as a neutron flux calculation error. Therefore, the magnitude of the background signal must be limited to within a certain fraction of the emitter signal level. One approach to reducing the background current signals is to minimize the sheath thickness; however, this is constrained by the requirement that the sheath must withstand the mechanical stresses encountered during operation. Alternatively, background wire type configurations that provide a lower background signal may also be adopted. Fig 1. Shows the separate background type SPND, Fig 2. show the background wire type SPND.

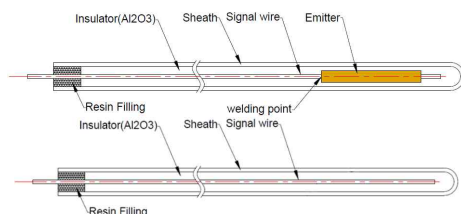


Fig 1. SPND and background detector

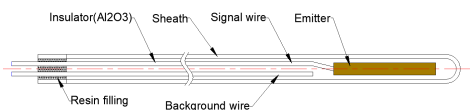


Fig 2. Compensation wire type SPND

In SPND with the added background wire, due to the competitive neutron absorption between the two conductor wires, the generation of current in the background wire is reduced.

In this study shows the results of signal characteristic comparison conducted through HANARO irradiation tests to determine the SPND type for i-SMR ICI

2. HANARO irradiation test

Two sets each of rhodium SPNDs, background detectors and background wire type rhodium SPNDs are fabricated, all having identical dimensions with a detector outer diameter 1.57mm, an emitter diameter 0.46mm, and then assembled in the irradiation rig.

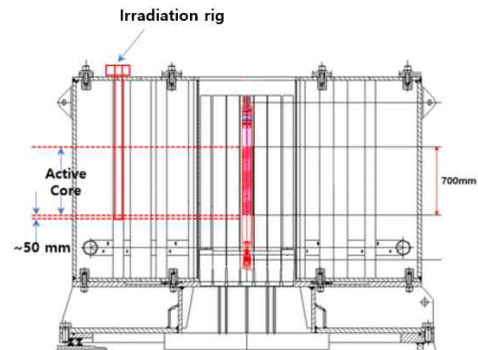


Fig 3. HANARO Core and Irradiation position

The IP5 irradiation hole, in which the neutron detector irradiation rig is installed, is located in the heavy-water region at an azimuthal angle of 65° from HANARO core center. To avoid neutron interference between adjacent detectors, the azimuthal spacing between detector positions was set to 30° .

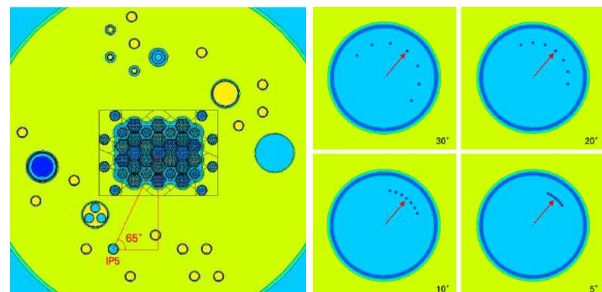


Fig 4. IP5 irradiation Hole and detector arrangement

3. HANARO irradiation test result

3.1 Detector signal linearity for power level

The irradiation test was conducted during HANARO 115th cycle, and detectors current signals were measured while increasing the power up to 23MW. During the power ascending, at power levels of 0, 9, 17, and 23 MW, the signals were recorded after maintaining 15minute stabilization period at each level. In Fig 5, the emitter current signal of the rhodium SPND and the background compensation wire type rhodium SPND showed a linear relationship with reactor power. In Fig 6, the background current signal also exhibited an overall linear trend with reactor power. Current values of separated background detectors were measured 8nA and 6nA, and two background wire-type detectors were measured 4nA.

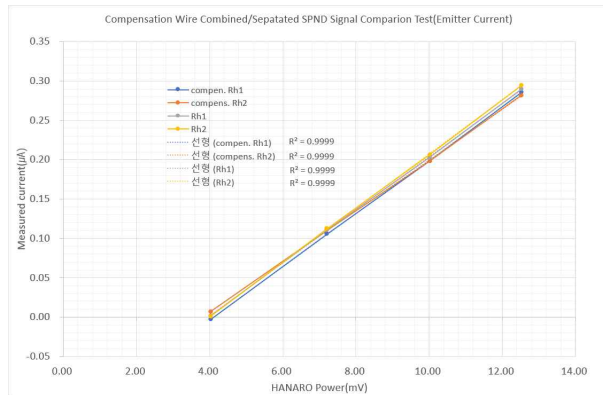


Fig 5. Emitter signal linearity for power level.

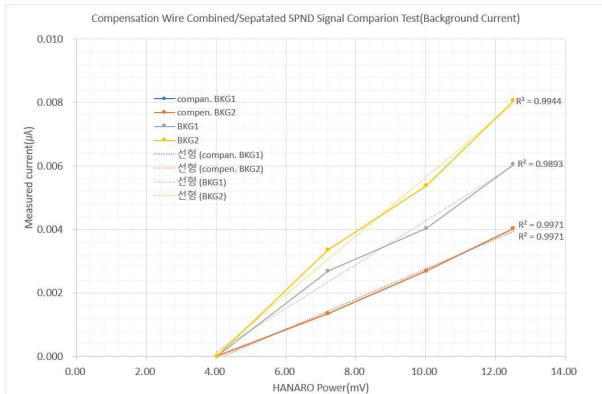


Fig 6. Background signal linearity for power level.

3.2 Detector signal error for power

Fig. 7 presents the emitter signal normalized to the power and the corresponding signal error. Due to the delayed response characteristics of rhodium, the emitter signal error increased up to 6% during the power ascending. Once the power reached 15minute stabilization condition, the error was observed -0.5% ~ 1.2%. Fig. 8 presents the background signal normalized to the power and signal error. The background signal exhibited prompt-response characteristics arising from

(n,γ,e) and (γ,e) reactions in the Inconel lead wire and sheath material. During both the power ascending and the stabilization conditions, the current magnitude and signal error tended to fluctuate -15%~15%. These behaviors are attributed to the relatively small background current levels and the signal processing system resolution.

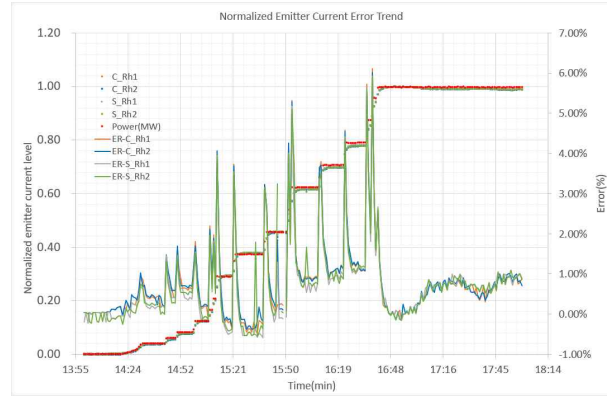


Fig 7. Normalized Rh emitter signal error for power.

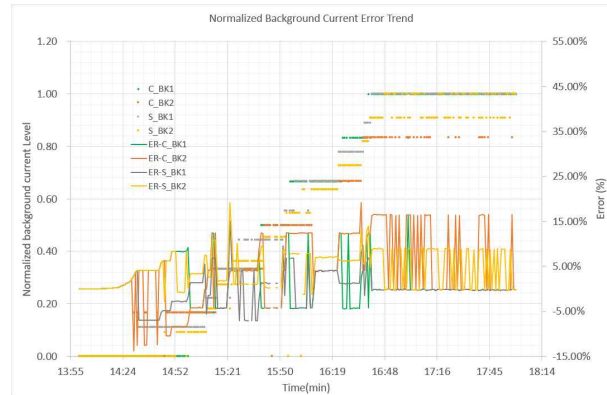


Fig 8. Normalized background current signal error for Power.

4. Summary and Conclusion

A comparative experiment was conducted to evaluate the signal characteristics of two types of SPNDs employing different background configuration. It was confirmed that the background current level of the background wire type was smaller than that of the separated background detector type. Four emitter current signal error for power was within $\pm 1.2\%$. Four background current signal error for power was $\pm 15\%$, due to resolution limitations of the signal processing system, and this error is believed to be reduced by increasing the background wire length exposed to neutrons.

REFERENCES

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[2] W. Jaschik & W. Seifritz, Model for Calculating Prompt-response Self-Powered Neutron detectors, Nucl. Sci. and Eng.: 53:1, 61-78, 1974.