Neutron Activation Analysis in the Irradiation Hole of the HANARO Research Reactor for Verification of Advanced Neutron Flux Detectors

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1. Introduction

The Korea Atomic Energy Research Institute (KAERI) and the French Alternative Energies and Atomic Energy Commission (CEA) are jointly conducting the CORANI (KAERI/CEA Collaboration for Research Reactor Application of Neutron Dosimetry and Instrumentations) project to enhance irradiation testing. This project is divided into two phases and aims to verify and demonstrate various advanced instrumentation sensors. Phase 1, scheduled for the second half of 2025, focuses on characterizing the neutron field using a new type of Self-Powered Neutron Detector (SPND) and Fission Chamber (FC). The experiments will be conducted at HANARO, KAERI's research reactor, which is a 30MW open-pool-type multi-purpose research reactor providing various neutron flux environments [1]. For precise neutron field analysis, Neutron Activation Analysis (NAA) using various activation foils is required. This study serves as a preliminary experiment for Phase 1 of the CORANI project, evaluating the neutron flux distribution at the center of the irradiation hole using AlCo, AlSc, Ag, Fe, Ni, and Sn-119.

2. Methods and Results

2.1 Target fabrication

The activation foils used in the experiment were fabricated at CEA's MADERE facility [2]. Most of the foils had dimensions of 4 mm in diameter and 0.1 mm in thickness. The foils were inserted into an inner container made of 3 mm thick aluminum and mechanically sealed. The inner container was then placed inside an outer target container with a thickness of 2 mm and sealed through welding in a helium atmosphere. A 2 mm thick aluminum tube spacer was used to prevent displacement of the inner container. The fabricated target container had a height of approximately 160 mm, and four target containers were stacked in a line inside an irradiation rig, which had a total height of about 1 m. Figure 1 illustrates the placement of the irradiation rig and the target containers within the irradiation hole.

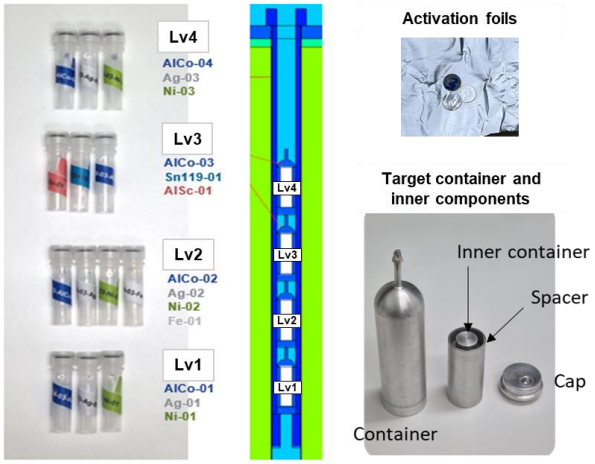

Fig. 1. Irradiation geometry (left) and images of the activation foil and container (right).

2.2 Irradiation and Retrieval

The irradiation was carried out in IP4. The irradiation rig was manually inserted into the irradiation hole through the upper hatch of the HANARO reactor pool. The reactor operated at a power of 13 MW, and the irradiation time was six hours. After irradiation, the rig was transferred to the service pool for cooling. The target containers were retrieved and dismantled at the Irradiated Material Examination Facility (IMEF) after a cooling period of 26 days. The samples were then analyzed using the High-Purity Germanium (HPGe) detector in KAERI's Pneumatic Transfer Irradiation (PTS) facility [3] and CEA's Mobile γ/x detector [4].

2.3 Measurement and Analysis

The measurement results obtained from the equipment at both KAERI and CEA are compared in Table I. While the differences were generally within acceptable limits, significant discrepancies were observed in the peak analysis of Fe-59 and Sn-119. In particular, the precise measurement of Sn-119 was only possible using CEA's Mobile detector. Figure 2

presents the neutron flux distribution at the center of the irradiation hole, derived using AlCo. The results show a parabolic shape reflecting the fuel geometry, indicating high reliability.

Table I: Measured activity of activation foils

Radio-nuclides	Dosi-meter	Target position	Specific activity (Bq/mg)		
			KAERI	MEDERE	Deviation
^{60}Co	AlCo	Lv1	3.42E+03	3.57E+03	4.0%
		Lv2	4.11E+03	4.29E+03	4.1%
		Lv3	3.97E+03	4.10E+03	3.2%
		Lv4	3.17E+03	3.26E+03	2.8%
^{46}Sc	AlSc	Lv3	1.71E+05	1.79E+05	4.5%
^{54}Mn	Fe	Lv2	-	9.55E-01	-
^{59}Fe			5.93E+03	1.92E+03	-1518%
^{58}Co	Ni	Lv1	5.19E+01	4.99E+01	-4.2%
		Lv2	6.82E+01	6.55E+01	-4.1%
^{110m}Ag	Ag	Lv1	7.32E+04	7.59E+04	3.5%
		Lv2	8.76E+04	9.11E+04	3.8%
		Lv4	6.64E+04	6.96E+04	4.5%
^{119m}Sn	Sn-119	Lv3	3.77E+02	2.33E+01	-1518%
			-	2,64E+1 (X-ray)	-

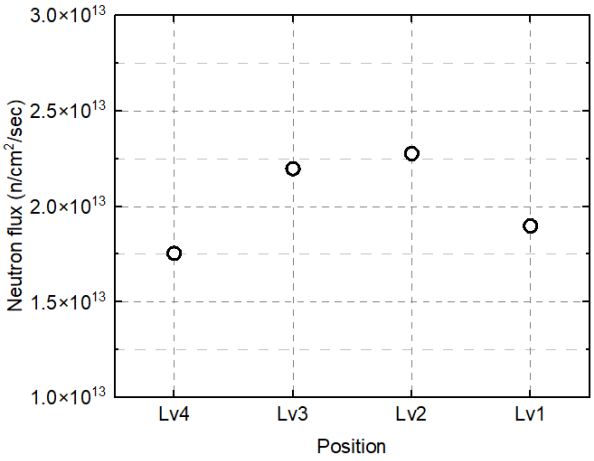

Fig. 2. Axial neutron flux distribution at the center of the IP4 irradiation hole evaluated using AlCo foil.

3. Conclusions

The CORANI project represents an important case of international collaboration for advancing neutron dosimetry and instrumentation technology in research reactors. This study presented the results of a preliminary dosimetry experiment for Phase 1 of the irradiation experiments to be conducted at HANARO. The experimental results confirmed that CEA's mobile spectrometry system has high reliability for precise X-ray and gamma-ray measurements. These findings provide crucial baseline data for the full-scale irradiation experiments scheduled for 2025 and are expected to contribute to the advancement of neutron and radiation monitoring technologies in the future.

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