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Experimental Evaluation of Potential Boron Contamination in Pb Shield of ASNC

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1. Introduction

KAERI has focused on upgrading a neutron coincidence counter for safeguards applications for last several years. As a result, the modified ACP-Safeguards Neutron Counter (ASNC) has been finally developed and tested for being applied to quantify the amounts of nuclear materials in spent fuels, e.g., uranium-235 or plutonium [1]. Because spent fuel emits a large amount of gamma-rays, the ASNC has lead shields to reduce gamma-ray events in the neutron proportional counter so that it can be used in high-radiation environments, e.g., a hot-cell environment. However, it was recognized that the shield manufacture facility conducts boron-relevant tasks, and boron is one of the most powerful neutron absorbers that have considerably large neutron capture cross-section [2] as much as used for reactor control rods. That is, it is probable that this potential boron contamination might be influential on the past performance tests of the ASNC, even if only small amount is included. Therefore, we examined that possibility through comparing the measured data with the simulated data using MCNP6 code [3]. This approach will be contributive to reduction of measurement uncertainty in nuclear material accountancy.

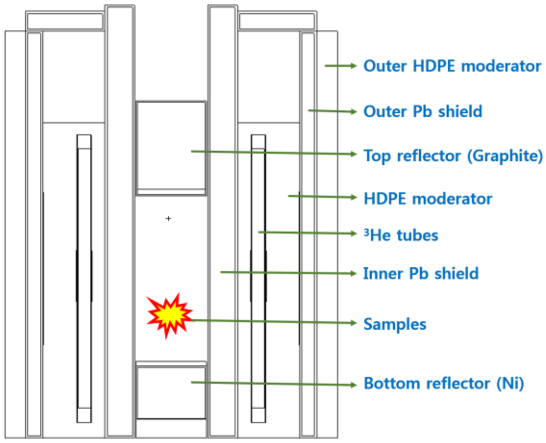

Fig. 1. Internal structure of ASNC (side-sectional view).

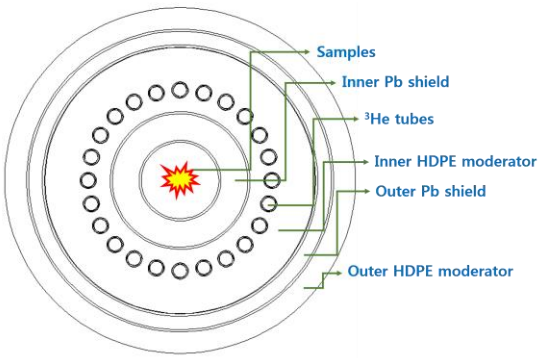

Fig. 2. Internal structure of ASNC (Top-sectional view).

2. Research Motivations

ASNC is a neutron coincidence counter based on ^{3}He proportional counters. Its internal structure was shown in Figs. 1 and 2. A sample will be put in the cavity, then neutrons and gamma-rays will be emitted from the sample. Gamma-rays will be firstly shielded by the inner Pb shield while neutrons can penetrate the shield. At the same time, the outer lead gamma shield, outer high density polyethylene (HDPE) neutron shield, and Cd absorber are installed to shield gamma-rays and neutrons from other materials in a hot-cell. Neutrons thermalized by the inner moderator will then be detected by the ^{3}He tubes. However, it was raised the Pb shields whose fabrication facility works boron-relevant tasks as well may contain a little amount of residual boron which is one of the most significant neutron poison material. Especially its cross-section in thermal region is very large, so even μg-level of boron results in considerable changes in nuclear measurements [4]. Because this effect had not been considered in detector characterization, we decided to evaluate whether the boron contamination in the shield does exist in this study.

3. Method to Confirm Boron in the Pb Shields

The tests to identify boron in the shields were performed for the inner Pb shield. Because it is detachable, measured and simulated detection efficiencies with and without the inner gamma shield were compared. The reason why comparing the measured efficiency with the simulated efficiency was that there is no boron in the simulation model [5]; hence, we can verify the difference if there is a boron contamination in the shield of the ASNC. If some amount of boron is actually in the inner lead shield of the ASNC, there should be a negative effect on the detection efficiency. As a result, with the boron contamination, the measured detection efficiency should be expected to be lower than simulated efficiency.

A ^{252}Cf calibration source (ID: L3-693, 1.56×10^5 n/s) was used in measurements. High voltage of 1720 V was applied and measurements were conducted 10 times with 30 seconds per each. The detection efficiency was calculated by singles count rates divided by neutron emission rates from the source.

4. Results and Discussion

Table I summaries measured singles and doubles count rates (cps) for the background and ^{252}Cf neutron source. Table II summaries the simulated and measured detection efficiencies for the cases of with and without the inner lead shield.

At first, in order to validate the simulation model, we compared the difference between the efficiency with and without shield for each simulated and measured data. The percent differences were 5.9% and 6.0% for the simulated and measured data, respectively. Because these two values were agreed well, we concluded that the simulation model for the ASNC is appropriate. Then, we compared the measured data with the simulated data for each with and without lead shield. The percent difference between the simulated and measured data was 1.7% and 1.8% for the cases of with and without the inner lead shield, respectively. The difference was comparable between the two cases and it would be originated from discrepancy in the simulation model or the uncertainty in neutron strength of the calibration source ($\sigma \approx 5\%$, in general). As a result, we concluded that the boron contamination in the lead shield was negligible.

Table I: Count rate for background and ^{252}Cf neutron source in a hot-cell

Background (cps)	**Singles**	0.703
	Doubles	0.023
^{252}Cf Neutron Source (cps)	**Singles**	38147 ± 16
	Doubles	9281 ± 44

Table II: Simulated and measured detection efficiency with and without inner Pb shield

Detection Efficiency (%)	**w/ Inner Pb Shield**	**w/o Inner Pb shield**	**% Difference**
Simulated	24.5	23.1	5.9
Measured	24.1	22.7	6.0
%Difference	1.7	1.8	

5. Conclusions

We tried to confirm whether there is any unintended effect in neutron measurement by boron contamination in the Pb shield. To this end, the measured and simulated data with and without the shield were compared to each other. As a result, the boron effect on the detection efficiency was expected to be negligible. In the near future, further test with the upgraded ASNC will be performed to evaluate its performance for actual spent fuels.

6. Acknowledge

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