Experimental Evaluation of Potential Boron Contamination in Pb Shield of ASNC

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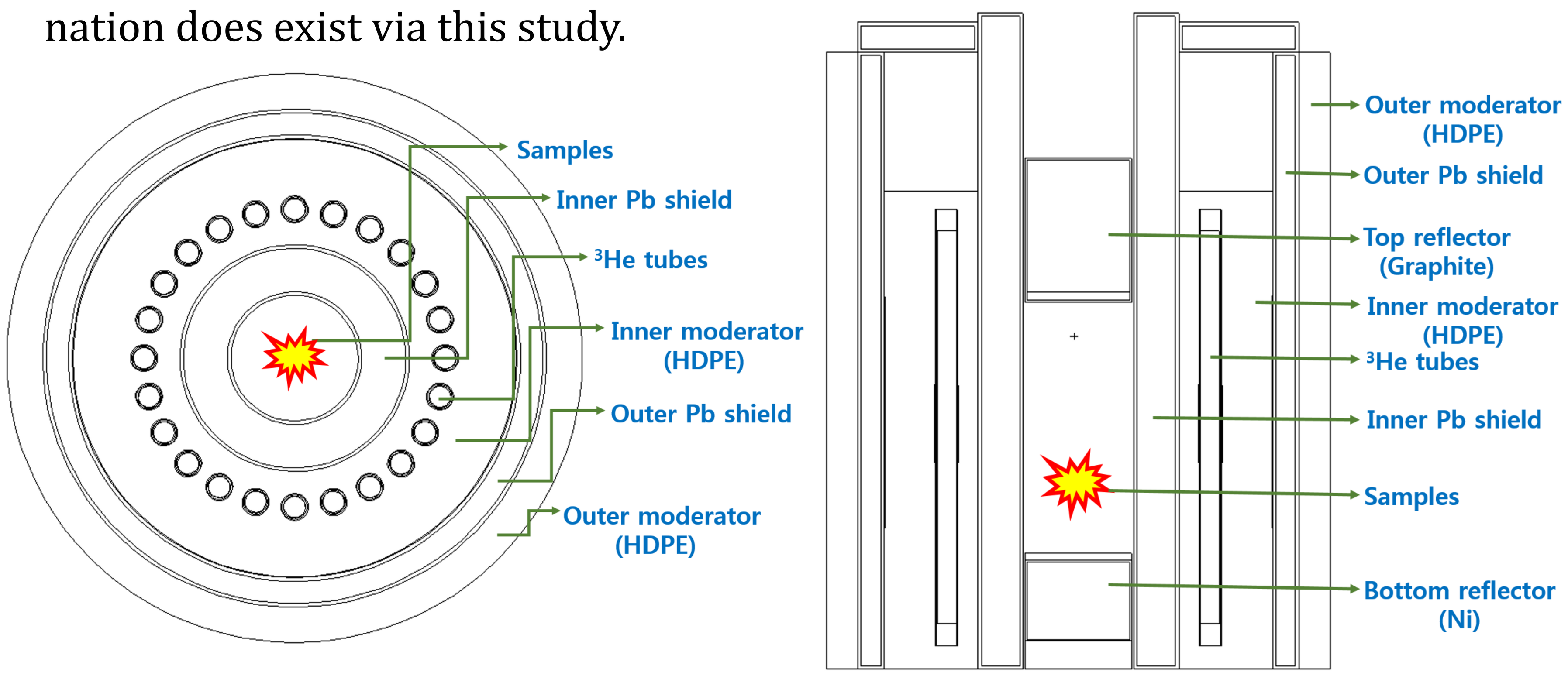
Abstract

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. Because spent fuels emit gamma-rays of considerable energy fluence, the ASNC has lead shields to reduce gamma-ray events 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 overwhelmingly large neutron capture cross-section 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 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. This approach will be contributive to reduction of measurement uncertainty in nuclear material accountancy.

Research Motivation

ASNC is a neutron coincidence counter based on ^{3}He proportional counters. Its internal structure was shown below. A sample will be put in the cavity, then neutrons and gamma-rays will be emitted from the center. Gamma-rays will be firstly shielded by the inner Pb shield while neutrons can penetrate the shield. At the same time, the outer Pb shield, outer high density polyethylene (HDPE) moderator, and Cd absorber are installed to interrupt 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 substantial changes in nuclear measurements as shown in the table below. Because this effect had not been considered in detector characterization, we decided to evaluate whether the boron contamination does exist via this study.



Method to Confirm Boron in the Pb Shield

The tests to identify boron in the shields were performed for the inner Pb shield. Because it is related practically to the detection efficiency of the ASNC. Measured and simulated detection efficiencies with and without the inner lead shield were compared. That is based on there is no boron in the simulated model; hence, it is possible to verify the difference dependent on boron contamination in the inner shield. If some amount of boron is actually in the shield, the measured detection efficiency is expected to be lower than simulated.

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.

Boron Conc (ppm)	Detection Efficiency (%)
0	24.61
1	24.54
2	24.48
3	24.42
4	24.37
5	24.32
6	24.27
7	24.22
8	24.18
9	24.15
10	24.11

Results and Discussion

The first table shows simulated detection efficiency corresponding to the boron concentration in the inner lead shield using MCNP6. The second table summaries measured singles and doubles count rates (cps) for the background and ^{252}Cf neutron source. The last table 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 efficiencies 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 fact that the both measured values are smaller than simulated would be considered as a negative result stemmed from boron contamination. However, the percent differences between the simulated and measured data were 1.7% and 1.8% for the cases of with and without the inner lead shield, respectively. Because the differences were comparable between the two cases, the differences might be originated from discrepancy in the simulation model or the uncertainty in neutron strength of the calibration source (σ≈5%, in general).

To clarify that, we could, primarily, confirm the detection efficiency is enhanced around 6% by installation of the inner Pb shield. Then, it was also observed that the increment for the measurement was larger than simulation which has not even decrement by boron. As a result, we concluded that the boron contamination in the inner lead shield is negligible.

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

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	-

Conclusions

We tried to confirm whether there is any unintended effect in neutron measurement by boron contamination in the inner Pb shield. The measured and simulated data were compared to each other, because it is possible to assume that results are not affected by boron in case of simulation. Also, we discriminated the negative effect of boron contamination from discrepancy in the simulation via comparison between the values which had been measured and simulated with and without the shield. As a result, the boron effect on the detection efficiency was expected to be negligible. Even though we confirmed no any negative effects by boron, this approach could be available to reduce uncertainty of measurement in nuclear material accountancy. In the near future, further tests with the upgraded ASNC will be performed to evaluate its performance for actual spent fuels.

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