Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Fabrication of Safeguards Neutron Coincidence Counter and Its Inner Structure

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1. Introduction

The Advanced spent fuel Conditioning Process Facility (ACPF) at KAERI has been refurbished for the test of an electrolytic oxide reduction process using spent fuels. Also, KAERI has manufactured process-related instru-ments as well as safeguards-related one. ACP Safeguards Neutron Counter (ASNC) has been developed to be tested for nuclear material accountancy (NMA) of the facility based on a coincidence neutron counting and the use of the ratio of Pu/^{244}Cm or ^{235}U/^{244}Cm, which can be determined from burn-up code calculations or chemical analysis [1]. One of the main roles of the ASNC is to confirm the applicability of a neutron coincidence counting in the hot-cell environ-ment which has high level of radiation field. This paper describes the detail description of the ASNC and simulation results based on the Monte Carlo simulations and irradiation test.

2. Components of ASNC

The components of the ASNC and their properties are described in this section. The ASNC consists of internal and external γ-ray shields, internal neutron moderator, external neutron shield, neutron reflectors, He-3 neutron detectors and associated signal processing circuits, source container, cabling box, and LED-based monitor-ing box (Fig. 1).

2.1 Inner γ -ray Shield

A γ-ray shield made of 5-cm-thick Pb, which was determined by Monte Carlo N-Particle code (MCNP) simulations and irradiation test, was manufactured to reduce the pile-up effect by γ-rays emitted from sources to be measured. Its materials are 96.8% of Pb and 3.2% of Sn, melted mixture to improve mechanical strength of Pb and processibility. A housing was made of 4-mm-thick Stainless Steel (STS304) considering the weight of the inner γ-ray shield.

2.2 Inner Neutron Moderator

Inner neutron moderator is used for moderating neutrons emitted from sources to make them easily

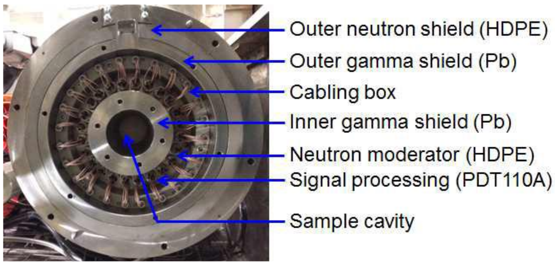

Fig. 1. Inner structure of fabricated ASNC.

detectable by a ^{3}He detector. Its material is a high density polyethylene (HDPE), which contains a plenty of hydrogen resulting in the superior moderation power. The thickness was decided to be having maximum efficiency in detection through MCNP simulations. In addition, a Cd sheet was installed at the middle height of the hole for placing the detectors to flatten axial efficiency.

2.3 Outer γ -ray Shield

An outer γ-ray shield was manufactured to eliminate γ-rays emitted from other sources in a hot-cell. This is based on the experience that the electronics had been frequently malfunctioning by accumulated dose from γ-rays in a hot-cell during long-term operation. Further-more, using the outer γ-ray shield can reduce pile-up effect in the neutron detector. The material is the same as the internal one.

2.4 Outer Neutron Shield

An outer neutron shield with HDPE was manufac-tured to reduce the background counts caused by neutrons emitted from other sources in a hot-cell. Incident neutrons are slowing down, and will be, eventually, absorbed by the outer neutron shield and/or Cd sheet, which is installed in the outside of the inner moderator. According to these, background and measurement error could be reduced.

2.5 Neutron Reflectors

A neutron reflector which is located in the upper and lower parts of the cavity increases efficiency through reducing neutron leakage, and decreases variation in the axial efficiency profile. The material used in the lower part of reflector is nickel. The housing is made of

STS304, and it has 3 mm of thickness. Nickel has positive properties as a neutron reflector, because it has high elastic scattering cross-section while low absorption cross-section; however, heavy weight is a disadvantage in terms of mechanical stability. Thus, the upper part of reflector is made of graphite.

2.6 ^{3}He Neutron Detectors and Electronics

Recently, there is a global shortage of ^{3}He gas [2], so the ^{3}He neutron detectors previously used in the ASNC was reused for cost savings. The quenching gas inserted in the detector to prevent unnecessary avalanches by UV lights is nitrogen gas. In the past, it had been difficult to extract ^{3}He-detector from the body by using a manipulator, because the inner structure was deformed over the course of many years. Therefore, a guide tube was embedded around the ^{3}He detector, and its material is Al (A6061) considering neutron absorption cross-section and mechanical strength. The electronics is a PDT 110A module (Precision Data Technology, USA) which has reasonable radiation resistance. This is an integrated signal processing circuit which includes functionalities of a charge-sensitive pre-amplifier, signal shaper, discriminator, LED driver, HV filter, and OR logic.

2.7 Source Container

Note that the most important factors considered to manufacture the modified ASNC are remote operation and maintenance capability. In this regard, a source container was fabricated to easily handle the sources in a hot-cell environment via a manipulator. There is a neutron reflector which is made of graphite and embedded in the source container. The source container is made of Al (A6061) considering low neutron absorption cross-section.

2.8 Cabling Box and LED-based Monitoring Box

A cabling box was manufactured to manage cables which transfer signals generated from detectors as well as supply HV and DC power to detectors and electronics, respectively. Considering remote operation capability, dedicated LEMO connectors were used. Also, the healthiness of each detector can be visually monitored outside of the hot-cell. The materials for the cabling box and the LED-based monitoring box are Al (A6061) and STS304, respectively. Table I summarizes the components and its properties.

3. Conclusion

KAERI has refurbished the ACPF hot-cell facility for the test of oxide reduction process using spent fuels, and manufactured process-related instruments as well as safeguards-related one. In this study, a neutron coincidence counter was fabricated for the test of a safeguards instrument in a hot-cell environment; hence, remote operation and maintenance capability were the important factors considered in design phase. In the near future, the modified ASNC will be installed in the hot-cell and tested with a standard Cf source in terms of various detector parameters and remote control capability.

REFERENCES

[1] Hee Seo et al., Development of ACP Safeguards Neutron Counter (ASNC), KAERI/TR-6594/2016, pp.1-29, 2016
[2] Dana A. Shea, Daniel Morgan, The Helium-3 Shortage: Supply, Demand, and Options for Congress, Congressional Research Service, pp.1-2, 2010

Table I: Components of ASNC and Its Properties

Component	Materials	Considered factors and methodology
Inner gamma ray shield	- 5 cm of thickness - 96.8% of Pb, - 3.2% of Sn - STS304 housing	- MCNP - Irradiation test - Pile-up effect - Mechanical strength
Inner neutron moderator	- HDPE - Cd (middle height)	- Detection efficiency - Axial efficiency profile
Outer gamma ray shield	- 96.8% of Pb - 3.2% of Sn - STS304 housing	- Past experience relevant to electronics - Long-term operation - Pile-up effect
Outer neutron shield	- High density polyethylene (HDPE)	- Background from other radiation sources
Neutron reflectors	- Graphite (upper part) - Nickel (lower part)	- Neutron leakage - Axial efficiency profile - Neutron elastic scattering cross section - Mechanical stability
^{3}He Neutron detectors	- Al (A6061) guide tube	- Neutron absorption cross section
Source container	- Al (A6061)	- Neutron absorption cross section
Cabling box	- Al (A6061)	-
LED-based monitoring Box	- Stainless steel (STS304)	-