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Fabrication of Safeguards Neutron Coincidence Counter and Its Inner Structure

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Abstract

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 instruments 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 environment 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.

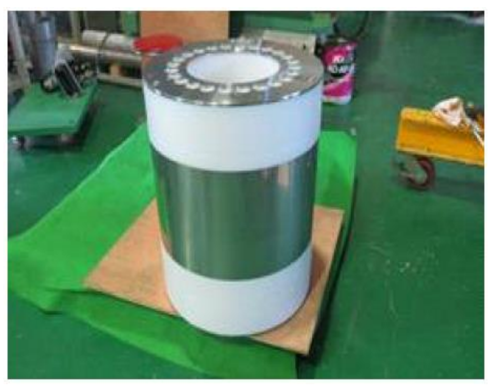
Design Concept

- ASNC is an advanced ^{3}He neutron proportional counter which can measure the amount of ^{244}Cm via neutron detection, and then the amount of Pu or ^{235}U can be calculated using the ratio of Pu/^{244}Cm or ^{235}U/^{244}Cm.
- Main objective of the modification is to reduce weight, volume and enhance especially remote operability, maintainability as well as detection efficiency.

Components of ASNC

- **Inner Gamma-Ray Shield**
  - For reducing the pile-up effect by γ-rays emitted from sources to be measured
  - 5cm of Pb-Sn alloy (Pb : 96.8%, Sn : 3.2%)
  - 4mm of Housing (STS304)
  - 14.2 cm (ID) × 82.2 cm (H) × 25.6 cm (OD)
  - Total weight : 302 kg

- **Inner Neutron Moderator**
  - For moderating neutrons emitted from sources to make them easily detectable by a ^{3}He detector.
  - 12cm of HDPE
  - Cadmium is installed in the middle height of the detector to cover 1/3 with to toward the cavity
  - 25.7 cm (ID) × 60.0 cm (H) × 49.7 cm (OD)
  - Total weight : 103 kg



- **Outer Gamma-Ray Shield**
  - For shielding γ-rays emitted from other sources in a hot-cell
  - Pb-Sn alloy (Pb : 96.8%, Sn : 3.2%)
  - Manufactured as higher than the moderator
  - 4mm of Housing (STS304)
  - 49.8 cm (ID) × 82.2 cm (H) × 56.3 cm (OD)
  - Total weight : 448 kg

- **Outer Neutron Shield**
  - For reducing the effect by neutrons emitted from other sources in a hot-cell
  - HDPE
  - A cadmium band is installed to surround the inner moderator : 1 mm (T) × 30cm (H)
  - 56.4 cm (ID) × 82.2 cm (H) × 64.5 cm (OD)
  - Total weight : 57.1 kg

- **Neutron Reflector**
  - For reducing leakage of neutrons to flatten axial detection efficiency

1)Upper Reflector
- Graphite, 3.78 kg
- 12.8 cm (D) × 17.0 cm (H)

2)Lower Reflector
- Nickel, 12.7 kg
- 13.5 cm (D) × 10.0 cm (H)

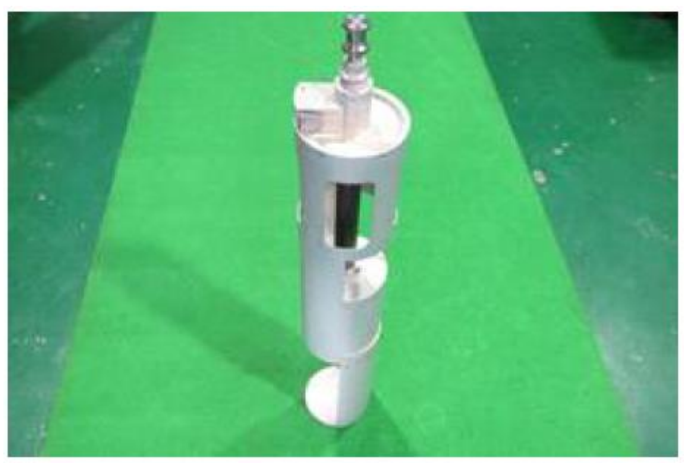
- **^{3}He Neutron Detector & Signal Conditioning Circuit**

1)^{3}He Detector
- Reused from previous ASNC
- Effective volume : 1.0 in (D) × 20.0 in (H)
- Fill Pressure : 4 atm
- 0.8 mm of Al (Quenching gas : N_2)

3)SCC
- PDT 110A

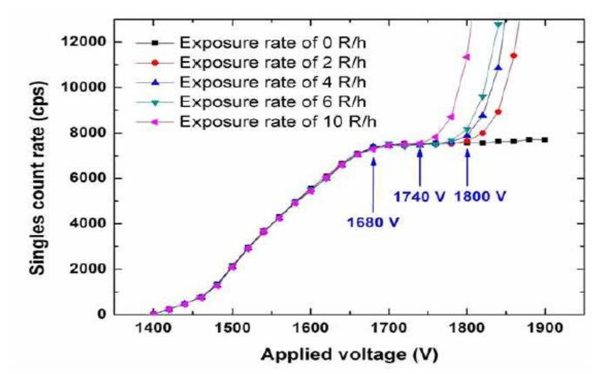
2)Guide Tube
- Installed around the ^{3}He detector
- A6061

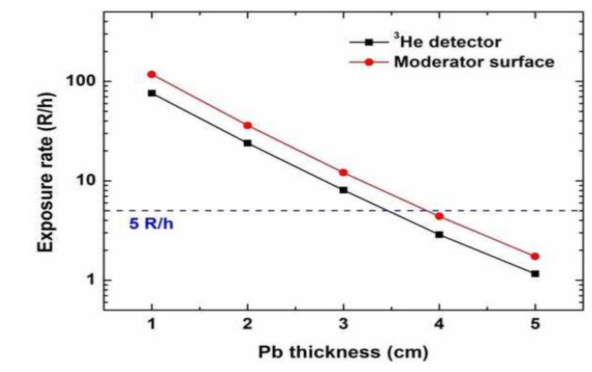
- **Source Container**
  - A Place in which a target source shall be located
  - A6061, Total weight : 7.8 kg
  - 3mm (T) × 14.0 cm (D) × 48.1 cm (H)
  - Cavity is embedded, 13.4 cm (D) × 26.0 cm (H)

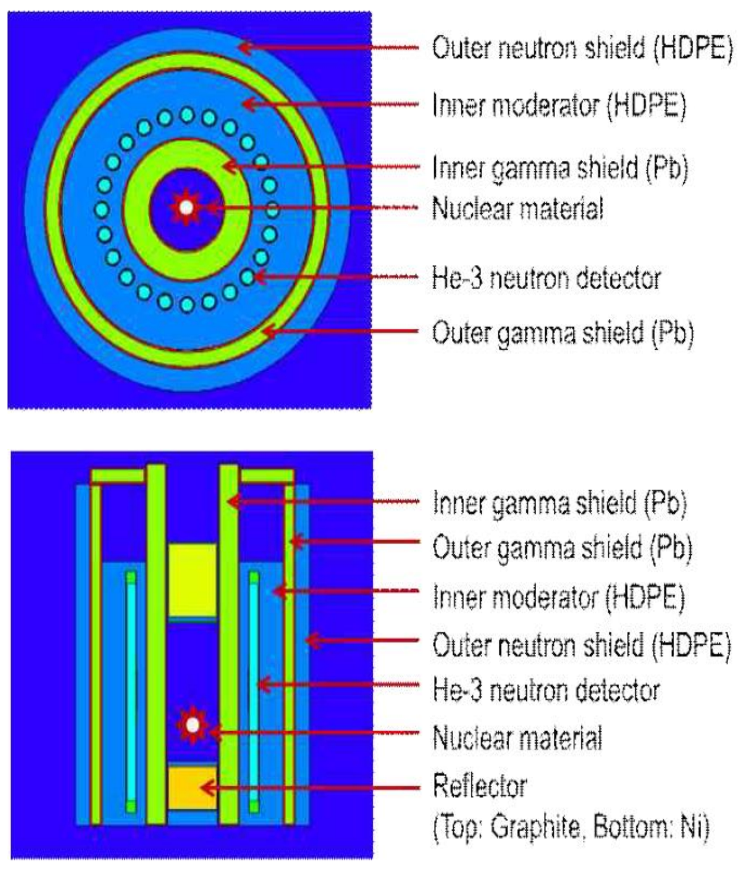


Modeling & Simulation for Design

- Gamma-Ray Irradiation Test & MCNP Calculation
  - Counting rate curve was complicating during irradiation of over 10 R/h of γ-ray exposure dose rate as a result of irradiation test.
  - It was decided conservatively to shield γ-ray exposure dose rate below 5R/h considering cases of detecting more amount of spent fuel.
  - The thickness (5 cm of Pb-Sn alloy, 12 cm of HDPE) was decided via Monte Carlo calculation to lower γ-ray exposure dose rate to less than 5 R/h.
  - Optimum thickness which is decided via those methods could contribute to improve detection efficiency.



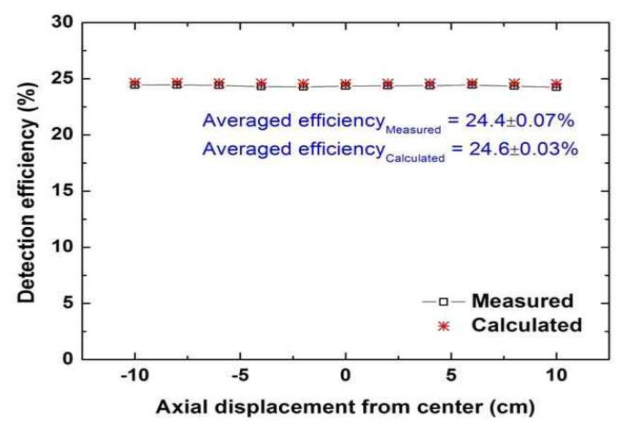


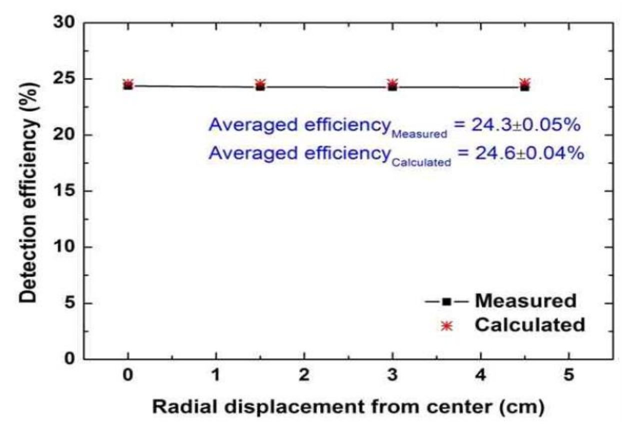


PURPOSE	Considered Factors	Relevant Things
Detection Performance	• Reduction of gamma-ray pile-up effect • Optimum thickness • Shielding neutrons from outside • Flattening axial efficiency • Malfunctioned components by irradiation • Decreasing background and errors • Increasing the number of carriers • Prevention of unnecessary Avalanche effect • Selection of materials • Improvement of radiation resistance	• Pb shield, Adjusting size of components • Irradiation test, MCNP • HDPE, CD • Optional installation of Cd, Reflectors • Inherent character of materials, shielding • Cd, Increasing the number of carriers • Moderation of neutrons from the target source, HDPE • Quench gas • Nuclear cross-section, A6061 • Activation resistance, PDT110A
Structural Reliability	• Using alloy • Radiation resistance • Selecting materials depending on locations • Structural change with time	• Solder • A6061, STS304, PDT110A • Nickel vs Graphite • Guide tube
Weight Spatial Efficiency Economical Efficiency	• Adjustment of thickness • Selection materials • Scarcity phenomenon	• Housing, MCNP • Solder(alloy) • Reuse, He-3
Remote Operability	• Selection of materials • Design of the source container • LEMO connector, etc	- - -

Results

- Detection Efficiency is 24.3% enhanced 16.8% compared to previous ASNC
- Total weight is 1.3 ton lighten 38.1% compared to precious ASNC
- The area occupied by ASNC in a hot-cell is decreased 41.9% compared to previous ASNC
- Remote operability and maintainability are improved





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. Nowadays, the modified ASNC has been installed in a hot-cell and tested with a standard Cf source in terms of various detector parameters and remote control capability. These achievements will contribute to improve reliability of the Pyroprocess in the near future.