Correlation between the canister's criticality and activity ratio of short-half-life noble-gas fission products under various fuel debris material compositions

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We investigated the possibility of estimating the effective neutron multiplication factor (k_{eff}) of the fuel-debris canister using remote gas-radioactivity measurement. The fuel-debris compositions inside a canister may vary and depend on the fuel-debris location inside the primary containment vessel and fuel-debris removal process. Our calculation result demonstrates the correlation between k_{eff} and the activity ratio of ^{88}Kr-to-^{135}Xe for the various fuel debris material conditions such as fuel burn-up degree before the accident of the Fukushima Daichi Nuclear Power Stations (1F), canister filling rate, water fraction, and fuel-debris type.

Keywords: Fuel Debris Canister, Subcritical System, Non-destructive Assay (NDA), Monte Carlo Calculation, Short Half-life Fission Products

1. Introduction

In this study, we performed neutron transport and subcritical depletion calculations for the canister filled with various fuel debris using a newly developed Monte Carlo depletion code [1]. The objective is to demonstrate that by measuring the activity ratio of ^{88}Kr-to-^{135}Xe of a fuel-debris canister, we can estimate canister criticality and other possible parameters without requiring prior detailed knowledge of the material composition and shape of fuel debris.

2. Calculation Method and Results

We performed a calculation of the canister filled with fuel debris from 1F Unit 2 with various conditions such as canisters filling rate, water contents, and types (molten fuel, uranium rich, molten-core–concrete interaction (MCCI)) to obtain the canister activity ratio of ^{88}Kr-to-^{135}Xe. We have successfully obtained the relationship between the activity ratio of ^{88}Kr-to-^{135}Xe and k_{eff} as shown in Figure 1. The figure shows, for the core averaged fuel isotope composition, the correlations between the activity ratio of ^{88}Kr-to-^{135}Xe and k_{eff} is almost linear and similar regardless of various fuel debris compositions introduced from canister filling rate, water contents, and types.

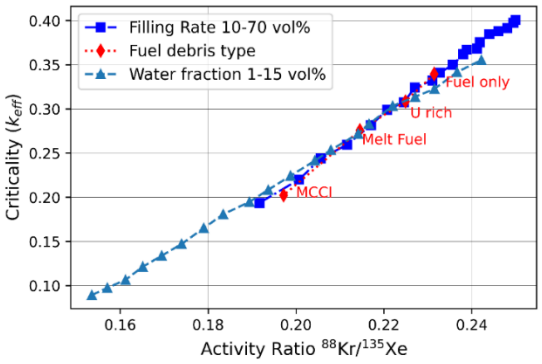

Figure. 1. Activity ratio of ^{88}Kr/^{135}Xe versus criticality (k_{eff}) of the canister under various conditions.

3. Conclusion

The depletion calculation for the subcritical canister filled with fuel debris using the newly developed Monte Carlo code has been successfully performed. The calculation result shows the relationship between the activity ratio of ^{88}Kr-to-^{135}Xe and canister effective multiplication factor (k_{eff}) is linear and similar regardless of various fuel debris compositions.

References: [1] Eka S. Riyana, et al., Journal Nucl Sci Technol. 2022; 59(4): 424–430.