Characterisation of UO_2 Spent Nuclear Fuel Samples containing Gd_2O_3 using SERPENT-2 Code

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Introduction

The degree of enrichment in **uranium dioxide (UO_2) nuclear fuels** has evolved to the extent that the associated excess reactivity at reactor start-up requires additional compensation through the addition of **gadolinium(III) oxide (Gd_2O_3)**. However, due to the increasing presence of Gd_2O_3, the accurate prediction of the isotopic evolution and power distribution throughout the irradiation cycles has a more significant impact on the fuel performance. Nevertheless, to date there have been no studies that have evaluated the **predictive capabilities** of the **SERPENT-2** nuclear depletion calculation code for low-doped UO_2-Gd_2O_3 fuel samples.

Method

Therefore, this master's thesis **models** selected UO_2-Gd_2O_3 Spent Nuclear Fuel (SNF) samples and **compares** them with experimental concentrations from destructive radiochemical analyses to evaluate the predictive capabilities of SERPENT-2. The simulation models incorporate SNF sample design data and reactor operating histories from the "Spent Fuel Isotopic Composition 2.0" database, which was developed by the Organisation for Economic Co-operation and Development Nuclear Energy Agency. The **eight selected SNF samples** were sourced from the Japanese Pressurised Water Reactors (PWRs) Takahama Reactor No. 3 and Ohi Reactor No. 2.

Takahama Reactor No. 3 "NT3G23" Assembly

The Takahama Reactor No. 3 "NT3G23" assembly was a 17 x 17 square lattice (Fig. 1) comprising 14 UO_2-Gd_2O_3 – which contain 6.00 wt% of natural gadolinium – fuel rods (*e.g.* "SF96") and 250 regular UO_2 fuel rods (*e.g.* "SF95") [1]. The **five UO_2-Gd_2O_3 SNF samples**, identified as "SF96-1" through "SF96-5", were positioned axially within fuel rod "SF96" (Fig. 2) and were irradiated for two consecutive cycles [2].

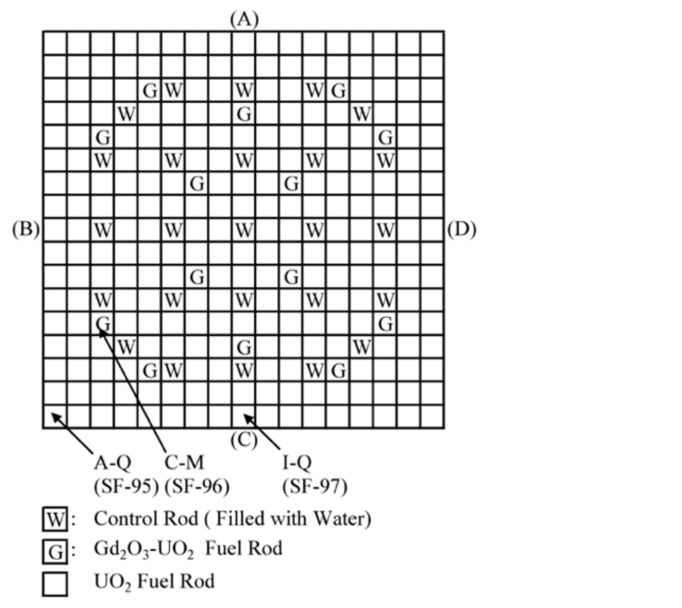

Fig. 1: Fuel rod configuration in the Takahama Reactor No. 3 "NT3G23" assembly

Fig. 2: Axial cutting positions of the five UO_2-Gd_2O_3 SNF samples in "SF96"

Ohi Reactor No. 2 "17G" Assembly

The Ohi Reactor No. 2 "17G" assembly was a 17 x 17 square lattice (Fig. 3) comprising 16 UO_2-Gd_2O_3 – which contain 6.00 wt% of natural gadolinium – fuel rods (*e.g.* "C5" and "O13") and 248 regular UO_2 fuel rods (*e.g.* "F4") [3]. The **three UO_2-Gd_2O_3 SNF samples**, identified as "C5-89G01", "C5-89G03", and "O13-89G05", were positioned axially within fuel rods "C5" and "O13" (Fig. 4), and were irradiated for two consecutive cycles [4].

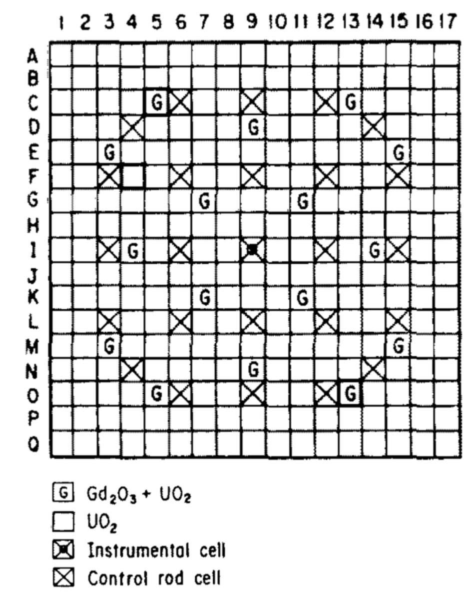

Fig. 3: Fuel rod configuration in the Ohi Reactor No. 2 "17G" assembly

Fig. 4: Axial cutting positions of the two UO_2-Gd_2O_3 SNF samples in "C5"

Results

Following the completion of the SERPENT-2 simulations, the **nuclide inventory predictions** were compared with the experimental measurements utilising the **'C/E-1' representation**. The experimental measurements – performed at the 'JAERI post-irradiation fuel examination facility' – were normalised to the date at which the irradiation was concluded. The nuclear data utilised in this study were obtained from the **ENDF/B-VII.1 evaluated nuclear data library**.

Takahama Reactor No. 3 'C/E-1' Results

Fig. 5 illustrates the results for the 'C/E-1' analysis of all the Takahama Reactor No. 3 SNF samples.

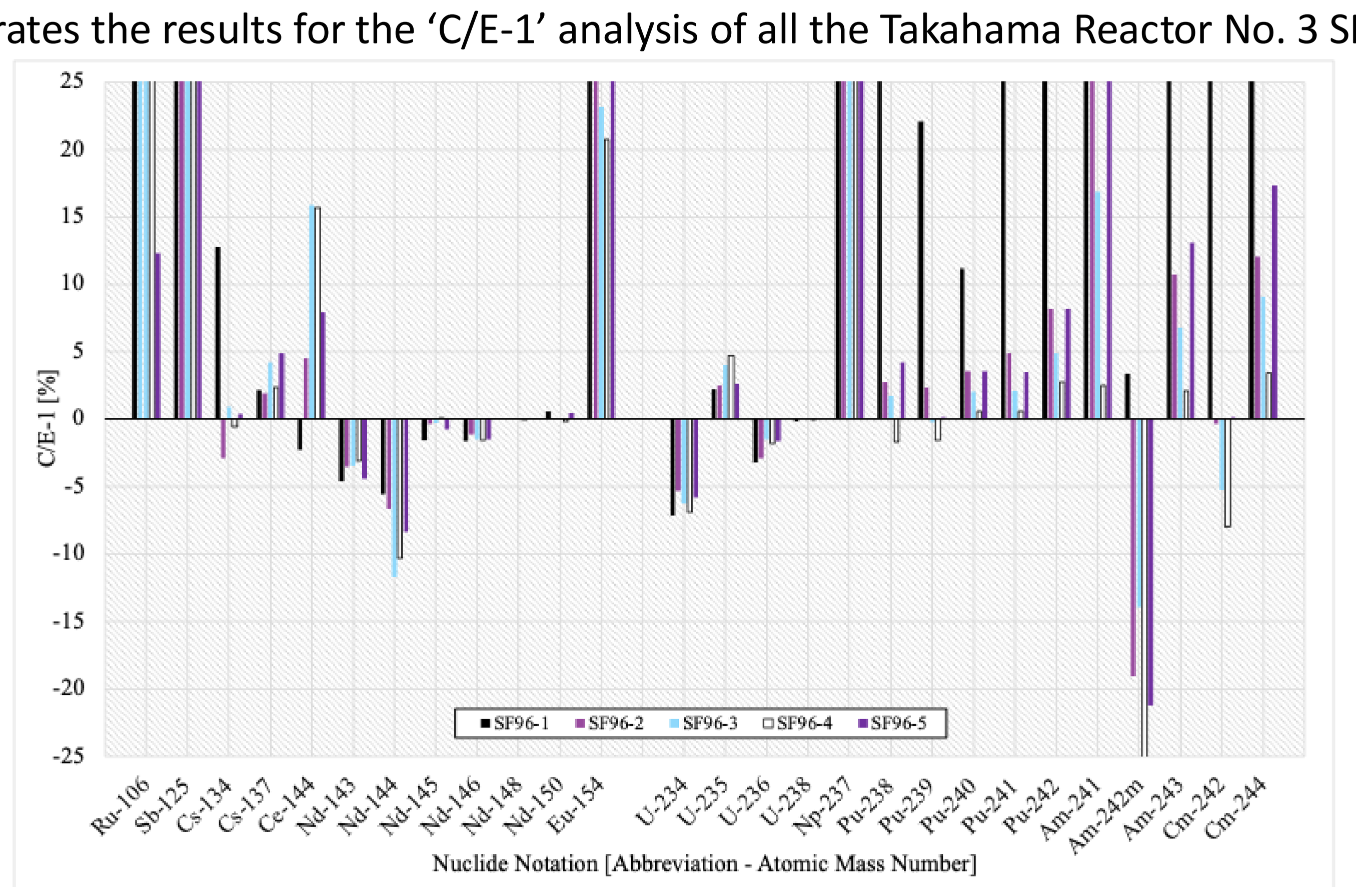

Fig. 5: 'C/E-1' results of the measured FPs and actinide nuclides of all the Takahama Reactor No. 3 SNF samples

Ohi Reactor No. 2 'C/E-1' Results

Fig. 6 illustrates the results for the 'C/E-1' analysis of all the Ohi Reactor No. 2 SNF samples.

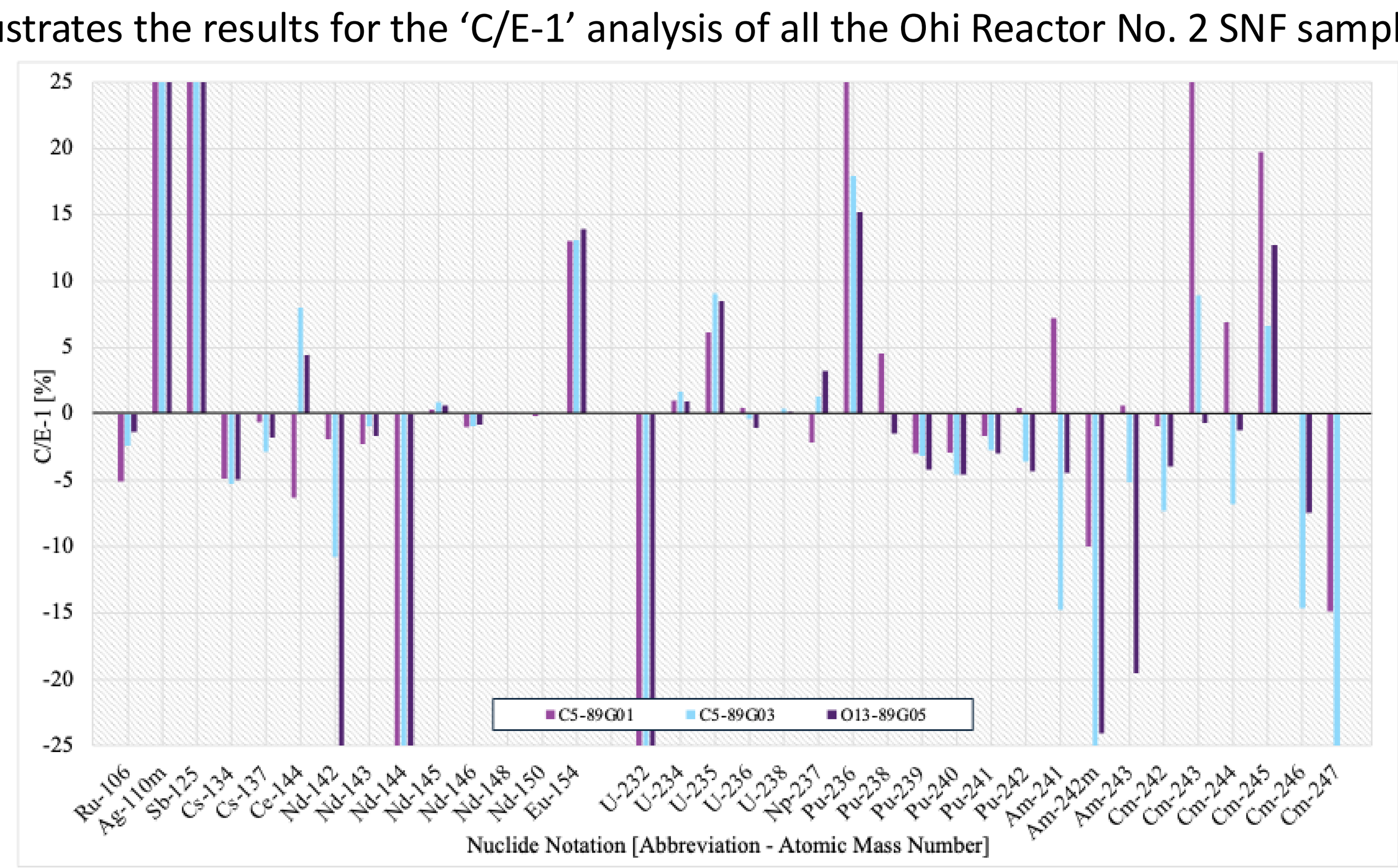

Fig. 6: 'C/E-1' results of the measured FPs and actinide nuclides of all the Ohi Reactor No. 2 SNF samples

Conclusion

For both investigated PWRs, the nuclide inventory predictions were in **good agreement** with the experimental results. Therefore, in the scope of validating PWR-SNF samples in which Gd_2O_3 is more prevalent, the **SERPENT-2** nuclear depletion code **can be utilised**.

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[3] K. Suyama, M. Murazaki, K. Ohkubo, Y. Nakahara, and G. Uchiyama, "Re-evaluation of Assay Data of Spent Nuclear Fuel obtained at Japan Atomic Energy Research Institute for validation of burnup calculation code systems," *Ann. Nucl. Energy*, vol. *38*, no. *5*, pp. *930-941*, May 2011, doi: *10.1016/j.anucene.2011.01.025*.

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