Study Regarding the Isotopic Inventory Evolution in the Case of ALFRED Fuel

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ABSTRACT

The isotopic inventory is an important source of information that helps in the detailed characterization of nuclear fuel during the different stages of its life cycle, from reactor operation through interim storage and final disposal in a permanent repository. This study investigates the isotopic inventory evolution of a MOX fuel assembly for the ALFRED demonstrator, during irradiation and in subsequent cooling. The objective considered is the fuel characterization, in the context of defining the modelling requirements for the construction of a digital passport. This document should contain the minimum amount of required information in order to aid the future users, and accompany the fuel assembly throughout its life cycle, solving in this way the issue of complexity reduction through the identification of relevant radioisotopes and selection of an adequate temporal granularity.

The study is performed using Serpent 2.2, with the ENDF/B-VI.8 and ENDF/B-VII.0 nuclear data libraries. The calculations were performed under ALFRED irradiation conditions, as well as post-operational conditions. The geometry of the hexagonal fuel assembly, containing 126 pins situated around a dummy pin, was modeled in detail. A scenario consisting of prolonged irradiation at constant power (reaching a burnup of 111 GWd/tHM in 2900 days at 2.24 MW), followed by a cooling period was considered. The study approaches the isotopic inventory evolution with the purpose of identifying the relevant nuclides that are to be considered for the digital passport.

Serpent code is computationally demanding, requiring considerable memory for detailed irradiation simulations at the fuel assembly level and, particularly, at the reactor level, within the expected runtimes for such calculations, which can range from several days to several weeks. The calculations are performed using optimization techniques aimed at reducing the computation time, at the expense of increased

memory requirements. In the case of insufficient memory resources, the calculations can still be performed with a significantly increased computational runtime. In this context, the use of computer clusters is recommended in order to efficiently perform simulations at the level of the fuel assembly, and potentially at the level of the entire reactor.

In this study, an analysis was performed on ^{129}I, ^{90}Sr, and $^{134,\ 137}$Cs isotopes. These were chosen for their biological impact and the health risks they pose, bioaccumulating in the human body (iodine in the thyroid, strontium in bones). The evolution of the inventory of these fission products has been studied for the irradiation period and a subsequent cooling period, noting the linear rate of accumulation and exponential decay rate. This methodology can be applied for a wide variety of isotopes. Specific selection criteria need to be defined in order to consider the relevant isotopes for the purpose of the aforementioned digital passport.