

Short communication

Spent fuel criticality and compositions evaluation for long-term disposal in a generic cask



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ABSTRACT

The Nuclear Energy Agency (NEA) Expert Group on Burn-up Credit Criticality Safety published a Benchmark with results obtained from simulations with some nuclear codes for a PWR-UO₂ nuclear fuel disposed of in a cask. The same situations were simulated at the *Departamento de Engenharia Nuclear/Universidade Federal de Minas Gerais* (DEN/UFMG) with the SCALE 6.0 (KENOVI/ORIGENS), MCNPX 2.6.0/CINDER and MonteBurns (MCNP5/ORIGEN2.1). Combinations of codes and nuclear data are slightly different from those used by the organizations who participate of the Benchmark. For k_{eff} time evolution, the results are very similar to the values obtained by the benchmark participants. For decay time evolution, the results obtained for several nuclides presented the expected behavior. Nevertheless, differences in the composition increase during the time specially using the MonteBurns code. These differences may be attributed to the libraries and methodology for choosing libraries to decay calculation and the number of days to a year considered to calculations.

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1. Introduction

In Brazil, the nuclear technology is an alternative, due to the high amount of uranium and thorium ores reserves. Today, Brazil has two nuclear power plants in operation and another one in construction. Nevertheless, due to the uncertainty in the Brazilian Nuclear Program during two decades, Brazilian universities and research centers discontinued the use and development of nuclear codes to simulate nuclear reactor. In 2008, it was announced the construction of Angra-3. From then on, the DEN/UFMG has been increased its research using nuclear codes and in 2013, a burn-up credit criticality safety studied was initiated.

The use of nuclear codes to perform reactor physics calculations like criticality safety, fuel isotopic depletion and radiation shielding, among others, is very common around the world. The simulations are done with two- or three-dimensional nuclear codes, through deterministic or stochastic methods. Three-dimensional nuclear codes involve complex geometries and the results, based on the used model and the cross-section library, commonly are more feasible than that obtained with two-dimensional ones.

In 2012 Organisation for Economic Co-operation and Development (OECD) published the study “Burn-up Credit Criticality Safety Benchmark Phase VII – UO₂ Fuel: Study of Spent Fuel Compositions for Long-Term Disposal” ([Organisation for economic co-operation and development, 2012](#)). The NEA Expert Group on Burn-up Credit Criticality Safety studied the ability of relevant computer codes and associated nuclear data to predict spent nuclear fuel isotopic compositions and corresponding effective neutron multiplication factor (k_{eff}) values in a generic spent fuel cask configuration over the time until 10⁶ years. Fifteen organizations of ten different countries submitted their results to OECD. The following decay codes were used: ACAB-2008, CINDER 90, DARWIN 2.0, DARWIN 2.1, SCALE 5.1, SCALE 6.0, SCALE 6.1 beta, ORIGIN 2.2-UPJ, ORIGIN-X-2008, PHOENIX 1.0.0a beta and TIBSO. The following criticality codes were used: SCALE 5.1, SCALE 6.0, SCALE 6.1 beta, MCNP-4C2, MCNP-5, MCNPX 2.4, MCNPX 2.5, MORET 4.B.2, MORET 5 and JENDL-3.3.

This benchmark was chosen because it is a very credible source of information, once all organizations used a methodology that involves a great deal of complexity in computer modeling of the system and material information. Although these benchmark simulations were done considering a generic spent fuel cask configuration, the methodology is important to simulate other casks types. Furthermore, some codes used are of the plenty domain at DEN/UFMG and obtain the similar results following the same

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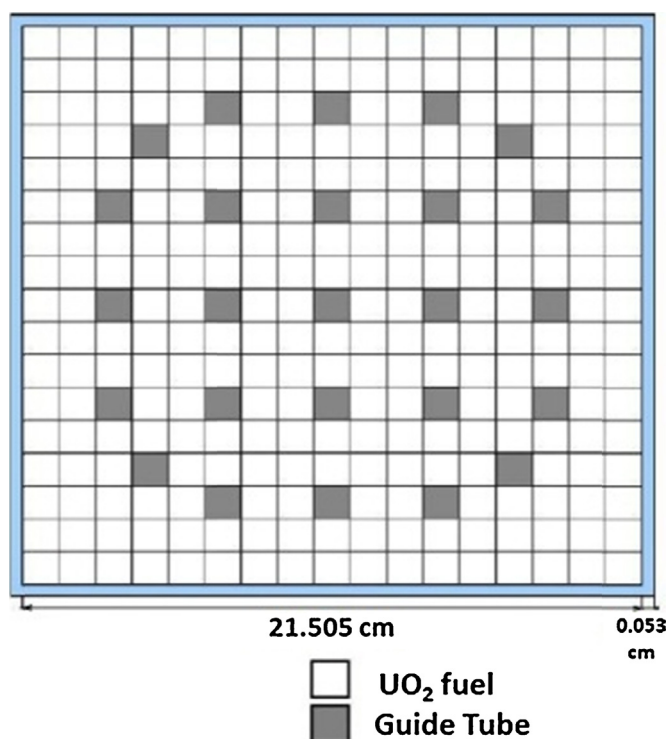


Fig. 1. UO_2 assembly geometry and guide tubes locations (Organisation for economic co-operation and development, 2012).

methodology used by the OECD-NEA will give us reliability to propose new projects in the future. In addition, the combination of codes and libraries used by DEN/UFGM are slightly different from those used by benchmark referenced.

In this work, the goal is to simulate the same benchmark with SCALE (Standardized Computer Analyses for Licensing Evaluation) 6.0, MCNPX (Monte Carlo N-Particle eXtended) 2.6.0 and Monte-burns that links the MCNP5 code with the ORIGEN-2.1 and compare the results with those published in Organisation for economic co-operation and development (2012).

2. The methodology

The model is based on a cask loaded with some isotopes from a PWR spent fuel with purpose of to calculate criticality along time. The OECD – NEA (Organisation for economic co-operation and development, 2012) designed this cask and it was loaded with fresh fuel and other two nuclides sets to perform criticality comparison and nuclide depletion or time dependent production.

The discharged fuel composition comes from an initial fresh fuel UO_2 enrichment of 4.5 wt% and 50 GWd/MTU burned-up, performed in a PWR assembly (17×17) by the Benchmark group with the geometrical features shown in Fig. 1 (Organisation for economic co-operation and development, 2012). The fuel rod dimensions are presented in Fig. 2 and the tube guide dimensions are shown in Fig. 3. The final composition, including fission products and actinides, will be loaded in the OECD cask to be used to calculate the criticality and the isotope decay along time.

The cask design contains 21-PWR assemblies as shown in Fig. 4, in which the assemblies are the same as previously described. A side view of the cask is shown in Fig. 5. Each assembly is embedded in a basket compartment with the dimensions described in Fig. 6. To compare, in the first step, the criticality calculation was performed for fresh fuel. The second step calculated the time-dependent criticality for the first nuclide set “SET 1” which contains only actinides

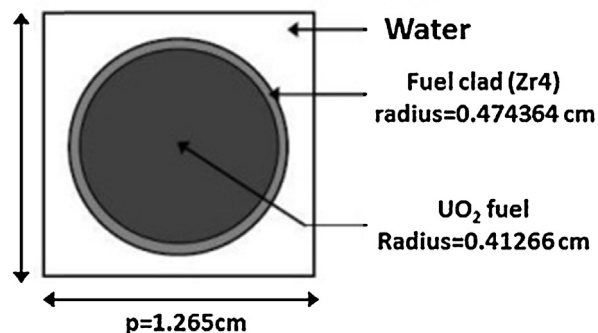


Fig. 2. Fuel rod geometry (Organisation for economic co-operation and development, 2012).

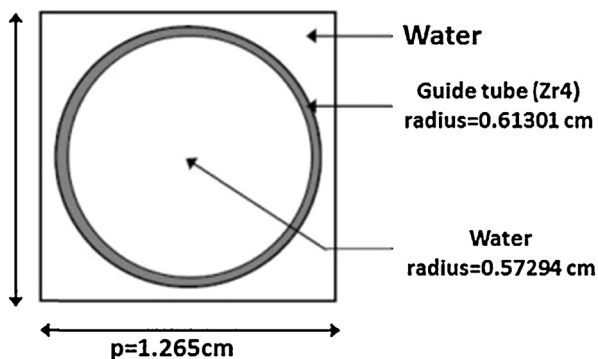


Fig. 3. Guide tube cell geometry (Organisation for economic co-operation and development, 2012).

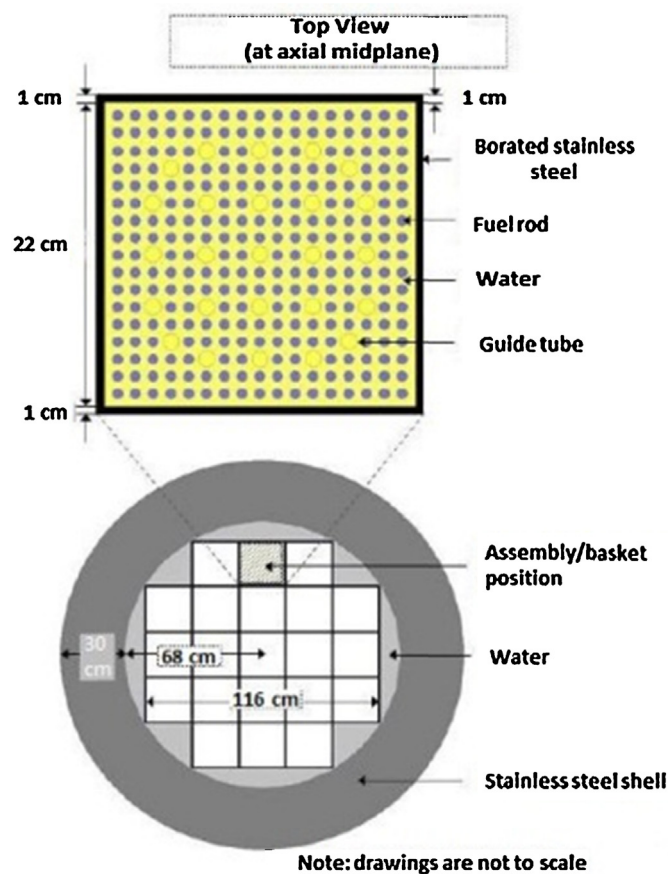


Fig. 4. Cask model – top view (Organisation for economic co-operation and development, 2012).

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