The Inventory Simulation of the Argonaut Nuclear Core Reactor

A. M. S. Alves[1], A. Heimlich[1], F. Lamego[1], C. M. F. Lapa[1]
E-mail: andersonmsalves@gmail.com, adino@ien.gov.br, flamego@ien.gov.br, lapa@ien.gov.br

[1] *Graduate Program of Nuclear Science and Technology, IEN*

Keywords: Argonaut reactor, fuel burnup, Runge-Kutta adaptive method

The Argonaut reactor is a water-moderated research reactor that was designed by the Argonne National Laboratory. There are currently few reactors of this type under operating conditions in the world, one of which, located at the Nuclear Engineering Institute in Brazil, has been in operation since 1965. This study analyzes a postulated accident caused by the collision of the reactor coverer into the core during crane manipulation. This event causes the release of particulate and volatile fission products into the reactor hall. Thus, it was necessary to evaluate the isotopic inventory and the fuel burnup for more than 50 years of operation [1]. Nuclear parameters such as radioactive decay, neutron capture probability, fission, etc., are characteristic of each nuclide. These data with the neutron flux allow us to model the inventory variation of each nuclide over time. The scalar neutron flux Φ represents the number of neutrons that cross an arbitrary area in all directions per unit of time. The fission reaction rate (RR) is given by the product between scalar neutron flux and the fission macroscopic section. By multiplying the RR per unit volume with the total volume of the nucleus, we obtain the total number of reactions per unit time. The mono-energetic neutron cross sections of capture and fission used in this study were obtained from the website of the Japan Atomic Energy Agency and the nuclei that are present in this study were chosen from the pressurized water reactor (PWR) option in the TAPE9 table of the code ORIGEN2 [2]. The Runge-Kutta method [3] is a family of algorithms used to obtain an approximate solution of Ordinary Diffential Equations. Theoretically, the method's objective is to provide a smooth map of time steps keeping the estimated error close to tolerance. This study analyzed the isotopic mass inventory of ^{235}U and ^{238}U given in Table 1, concluding that the fuel is virtually fresh. The dose rates related to the radioiodine are shown in the Table 2, which strongly impact the total dose. Table 3 shows volatile fission yields analyzed in this study.

Table 1 – Uranium inventory in Argonaut core

Nuclide	**Mass (g)**
^{235}U	2.09E+03
^{236}U	8.74E-02
^{237}U	1.53E-12
^{238}U	8.41E+03
^{239}U	5.87E-08

Table 2 – Iodine inventory in Argonaut core

Nuclide	Mass (g)	Activity (Bq)	Dose (mSv.h^{-1})
^{130}**I**	1.56E-06	1.12E+11	4.23E+05
^{131}**I**	2.43E-05	1.12E+11	8.54E+05
^{132}**I**	2.90E-07	1.11E+11	4.26E+05
^{133}**I**	2.66E-06	1.11E+11	1.22E+05
^{134}**I**	1.15E-07	1.13E+11	4.81E+05
^{135}**I**	1.02E-06	1.33E+11	3.09E+05
^{136}**I**	3.60E-09	1.32E+11	4.46E+05

Table 3 – Fission yield of volatiles

Nuclide	Mass (g)	Activity (Bq)	Dose (mSv.h^{-1})
^{85m}**Kr**	2.16E-08	6.58E+09	2.85E+04
^{85}**Kr**	7.05E-06	4.24E+06	1.77E+01
^{86}**Br**	7.91E-11	2.68E+10	2.84E+04
^{132}**Te**	3.53E-06	4.03E+10	3.04E+05
^{133}**Te**	9.84E-09	4.12E+10	6.51E+04
^{134}**Te**	6.05E-08	7.52E+10	1.30E+05
^{133}**Xe**	3.62E-07	2.51E+09	6.67E+03
^{135m}**Xe**	2.54E-05	1.75E+09	1.49E+04

The dose rate in the initial instant was calculated at a distance of 100 cm. Notwithstanding, the reactor room was not designed to contain the volatile and gas inventory that would be released in an accident. The entire atmosphere of the hall is replaced by the exhaust system, thus releasing the volatile elements to the environment.

References

[1] ALVES, A.M.S.; HEIMLICH, A.; LAMEGO, F.; LAPA, C.M.F. The Inventory and Source Term Simulation of the Argonaut Nuclear Reactor Inside a Severe Accident. Nuclear Technology. 207:2 (2020) 316-322.
[2] ISOTALO, A.; PUSA, M. "Improving the Accuracy of the Chebyshev Rational Approximation Method Using Substeps," Nucl. Sci. Eng., 183:1 (2016) 65-77.
[3] DORMAND, J. R.; PRINCE, P. J. "A Family of Embedded Runge-Kutta Formulae," J. Comput. Appl. Math., 6:1 (1980) 19-26.