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Estimation of the Amounts of Curium and Americium Isotopes in SNF of the BN-600 Reactor

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Abstract

The neutron-physical characteristics of curium and americium in spent nuclear fuel (SNF) of the BN-600 reactor were considered in the work. With the help of the Serpent software complex, several models of the BN-600 reactor fuel assembly with different enrichment of fuel by U-235 were built. In BN-600, with the probability of dividing Am-241 by no more than 15%, incomplete burning of minor actinides (MA) occurs and even the accumulation of Cm-244, which is dangerous for storage.

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1. Introduction

Considering nuclear energy as a large-scale and long-term method of energy production, it is necessary to develop and justify an effective method of destroying harmful wastes of this production [1].

Long-lived radionuclides accumulated in SNF are MA. The isotopes of americium and curium contribute greatly to the radioactivity of SNF and represent the greatest danger to the environment. It follows that prior to placement in the long-term storage of MA extracted from SNF, it is expedient to conduct their preliminary irradiation with the aim of destroying americium and curium [2-3]. Curium isotopes are also intense sources of spontaneous fission neutrons.

The article presents the results of numerical simulation of the burning of uranium oxide fuel in the neutron spectrum of the BN-600 reactor.

2. Materials and methods

The problem was to find the quantities of curium and americium isotopes in SNF of the BN-600 reactor for one fuel company.

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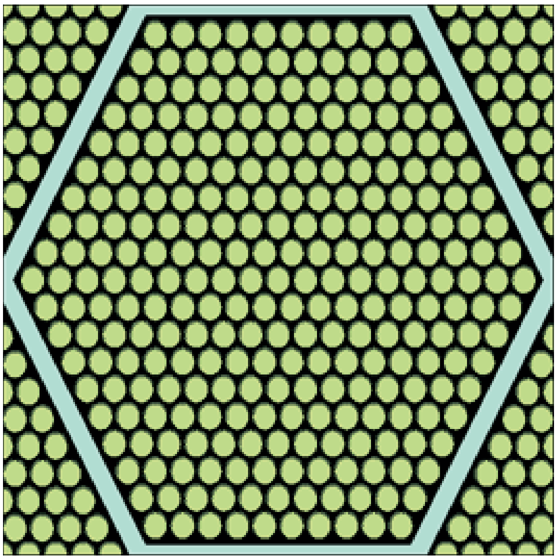

Figure 1: Fuel assembly of the BN-600 reactor in the Serpent software package.

The calculations were carried out using the Serpent [4] software package using the technical characteristics of the BN-600 reactor. As fuel, UO_2 was considered. The nuclear data library ENDF / BVII was used. To reach the critical regime, uranium enrichment in uranium-oxide fuel was 26%.

According to the received data, the amount of Am-241 produced in the core in BN-600 for a year of effective work. In the future it is supposed to make similar calculations for BN-600 with MOX-fuel, with the percentage of Pu-239, at which, the original K_{inf} is the same as with dioxide.

3. Results and discussion

Figure 1 shows the obtained model of the fuel assembly of the BN-600 reactor.

The results of the calculations are shown in Table 1, which shows the concentrations of americium nuclei and curium.

Table 2 shows the values of K_{inf} (the effective neutron multiplication factor in an infinite medium) during the burnout.

Table 1 shows that Am-241, Cm-244, Cm-242, Cm-243 contribute greatly to the radioactivity of SNF.

Figure 2 shows the formation of Am-241 nuclei during the reactor campaign.

Since the calculated concentration of Am-241 nuclei in the A3 turned out to be equal to 3,65E+16 ppm / cm^3, and the volume of the BN-600 in the core - 3.4E+ 6 cm^3, the number of Am-241 nuclei equal to 1,2 E+23 nuclei. The mass of one nucleus Am-241 is

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Table 1: Concentrations of the Cm-240, -241, -242, -243, -244, -245, -246 and Am-241 nuclei of the BN-60 reactor fuel assemblies for 330 effective days.

Isotopes	Concentration, nuclei / cm3	Weight, g / cm3
Cm-240	2,20E+01	1,26E-21
Cm-241	1,99E+04	1,14E-18
Cm-242	4,81E+11	2,76E-11
Cm-243	1,79E+09	1,03E-13
Cm-244	1,56E+09	8,96E-14
Cm-245	8,91E+06	5,12E-16
Cm-246	3,17E+04	1,82E-18
Am-241	3,65E+16	2,09E-06

Table 2: Change of K_{inf} in the core within 330 days.

Time, days	K_{inf}
0	1,31856
30	1,31539
80	1,30855
130	1,3015
180	1,29592
230	1,28764
280	1,28157
330	1,27644

4E-22 grams. The weight of the Am-241 produced in the core for a year of effective operation of the BN-600 reactor, assuming one zone with U-235 enrichment of 26%, reaches 48 grams of ecologically extremely dangerous isotope.

4. Conclusion

The report deals with the content of isotopes of americium and curium in the spent nuclear fuel of the BN-600 reactor.

With the help of the SERPENT software complex, several models of the BN-600 reactor fuel assemblies with different enrichment of fuel by U-235 were built. The results of numerical modeling of burning of uranium-oxide fuel in the fast neutron spectrum are obtained.

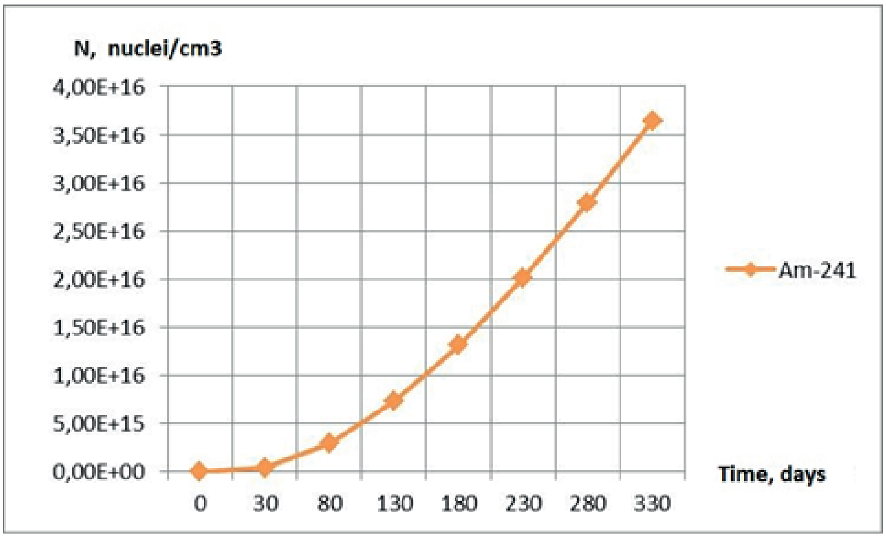

Figure 2: Am-241 concentration change during burnup.

In BN-600, with the probability of dividing americium-241 by not more than 15%, incomplete burn-up occurs: in a year of operation, up to 48 grams of Am-241 is produced, and Cm-244, which is dangerous for storage, is produced.

In the long term, when the BN type reactors are converted to MOX fuel, the operating time of the MA can increase.

Therefore, it becomes necessary to burn out MA in reactors with a more rigid neutron spectrum, with an average neutron energy in the AS greater than 0.5 MeV in BN.

Such reactors can be fast lead reactors with metallic fuel, for example a BRUC-M4 reactor, proposed at the Obninsk Institute of Nuclear Power Engineering of the National Research Nuclear University «MEPhI» in the Department of Nuclear Physics.

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