TRANSMUTATION OF MINOR ACTINIDES IN A MOLTEN SALT REACTOR AS A WAY TO REDUCE THEIR RADIATION HAZARD

M. N. Belonogov, I. A. Volkov, N. D. Dyrda, D. G. Modestov, D. V. Khmelnitsky

FSUE «RFNC – VNIITF named after Academ. E. I. Zababakhin», Snezhinsk, Russia

One of the possible ways to reduce the activity of radioactive waste in the long term is the extraction minor actinides (MA – Np, Am, Cm) from spent fuel of power reactors and their transmutation a specialized molten salt burner reactor (MSR-burner) [1–3]. Transmutation is understood as the conversion of these nuclides into fission products, as well as the actinides formed from them.

The report briefly presents the results of previous studies [1, 2]:

1. the existence of a transmutation mode without the need for additional Pu feeding has been demonstrated, which is achieved by maintaining a concentration of actinide fluorides ~10–15%, mol.;

2. MSR-burner with a thermal capacity of 800 MW based on salt of molar composition (%) 46,5LiF–11,5NaF–42KF in this mode consumes only ~250 kg/year MA. The integral consumption of Pu before reaching equilibrium mode will be ~5–10 t;

3. at a concentration of actinide fluorides of 3%, mol. which is typical for salts based on LiF and BeF_2, to ensure the same productivity of MA transmutation it is necessary to increase the thermal power to 1800 MW. In this case, in the equilibrium mode, the consumption of Pu will be 300 kg/year; the integral consumption before reaching the equilibrium mode will increase by ~4 times;

4. the features of MSR-burner is the accumulation during operation even plutonium isotopes, including highly active ^{238}Pu and ^{240}Pu; an increase in the proportion of Cm in MA due to an increase in the concentration of alpha-active ^{242}Cm and ^{244}Cm.

The purpose of this work is to estimate the radiation characteristics of MA and the nuclides formed from them for two handling options: storage of MA and their transmutation into MSR-burner. The characteristics considered were the activity and effective dose when ingested with food, equal to the product of the nuclide activity and its dose coefficient from the NRB-99/2009. The calculations considered salts of molar compositions (%) 46,5LiF–11,5NaF–42KF and 73LiF–27BeF_2.

As a result of the calculation studies, the following was obtained:

1. the degradation of the isotopic composition of Pu leads to an increase in its activity, which is approximately twice as high as that of the original MA, with comparable heat release; the effective dose increases by three orders of magnitude. This may cause difficulties when using such Pu as fuel for modern power reactors. Therefore, such Pu can be considered as radioactive waste;

2. only after 250 years of operation of the MSR-burner and 150 years of cooling, the activity of actinides in the salt, their losses and accumulated fission products becomes less than the activity of the original MA in the case of their storage. The decrease in alpha radiation activity relative to the initial MA begins after 50 years of operation of the MSR-burner and ~90–150 years of cooling. Moreover, the relative decrease increases with the increase in the duration of operation of the MSR-burner;

3. if we do not take into account the radiation characteristics of actinides dissolved in the fuel salt, which corresponds to the limiting case of long-term operation of the MSR-burner in equilibrium mode, the alpha radiation activity and the effective dose after 50 years of operation and 100 years of cooling decrease relative to the initial MA by 91–98%.

The obtained results indicate that for effective transmutation of MA, long-term operation of the MSR-burner with replacement of exhausted equipment are necessary.

References

1. **Belonogov, M. N.** On an Optimal Minor-Actinide Transmutation Regime in a Molten-Salt Reactor [Text] / M. N. Belonogov, I. A. Volkov, D. G. Modestov, et al. // Atomic energy. – 2020. – Vol. 128. – Iss. 3. – P. 143–150.

2. **Belonogov, M. N.** Comparative Analysis of Transmutation in a Burner Reactor Based on the Salts LiF–NaF–KF and LiF–BeF_2 [Text] / M. N. Belonogov, I. A. Volkov, D. G. Modestov, et al. // Atomic energy, 2022. – Vol. 132. – Iss. 4. – P. 202–207.

3. **Ignatiev, V. V.** Reactor with Circulating Fuel Based on Molten Metal Fluorides for Np, Am, Cm Incineration [Text] / V. V. Ignatiev, S. S. Abalin, M. Yu. Gurov, et al. // Atomic energy. – 2020. – Vol. 129. – Iss. 4. – P. 122–126.