CALCULATED INVESTIGATION OF ACTINIDE TRANSMUTATION IN THE BOR-60 REACTOR

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In the course of reactor operation the formation of fission products and accumulation of minor-actinides (MA) and plutonium take place in the nuclear fuel. These materials define the radiation hazard to a great extent. One possible way to lower the activity of irradiated nuclear fuel is transmutation of long-lived radioactive isotopes in the stable or short-lived forms, that allows facilitation of the problem of the highly-active waste and improvement of the efficiency of nuclear fuel use at the expense of increased recycling and burnup.

As numerous investigations demonstrate, the minor-actinide transmutation is possible in the thermal and fast power reactors. However, the most effective actinide burnup can be achieved at a special actinide burner-reactor only. These reactors provide a purposeful realization of optimum characteristics for actinide transmutations, which are "hard' spectrum and high density of neutron flux, a small factor of nuclear fuel breeding as well as stable neutron-physical features, that allows loading of a considerable amount of actinides to the core without an important influence on the reactor (primarily on safety). One of the prospective actinide burner reactor type is the fast reactor with a "hard' spectrum and small breeding factor, which is the BOR-60. The calculated investigations demonstrate that loading up to 40% of minor-actinides to the BOR-60 reactor did not lead to the considerable change of neutron-physical characteristics.

The BOR-60 reactor can be considered as optimum for demonstration of burnup efficiency of minor-actinides and plutonium, because the fraction of neutron flux density at energies above 0,1 MeV makes-up 73-86%, neutron flux density – up to $3{,}55 \cdot 10^{19}\, m^{-2}s^{-1}$, mean neutron energy in the core – 200-390 keV, negative effect of sodium void reactivity (- 0,052-0,068 Δk), small breeding factor (<0,28), and experimental opportunities of reactor facility. During 30 years of operation of the BOR-60 reactor significant calculated-experimental experience has been gained. The BOR-60 reactor provides to investigate and evaluate the possibility and efficiency of minor-actinide and plutonium transmutation:

- calculated investigation of critical mass, neutron-physical characteristics of reactor fuel with various minor-actinide compositions, and their quantitative and qualitative behavior in time;
- carrying out experiments on the definition of the main neutron-physical characteristics (flux density, neutron spectrum, reaction rate, etc.), change of nuclear fuel composition (burn-up, isotopic kinetics, etc.), separate fuel assemblies, fuel elements, capsules and reactor as a whole, comparison of experimental and calculated investigation results;
- testing and adaptation of the BOR-60 program and constant provision in order to improve the calculation accuracy of neutron-physical characteristics.

The BOR-60 reactor has gained significant experience on the operation with power-grade plutonium (the reactor was converted to MOX fuel in 1980). The standard fuel assemblies are irradiated to 20% of h.a. The separate fuel assemblies and fuel elements demonstrate a record value of fuel burnup up to 35% h.a. At present, a great number of fuel assemblies involving weapon-grade plutonium was irradiated. The experimental fuel assemblies containing different types of nuclear fuel and capsules incorporating practically all minor-actinides were irradiated and their irradiation is being continued in the reactor.

A regularly performed comparison between calculated and experimental data concerning the nuclear fuel burnup in the fuel assemblies and minor-actinides in the capsules demonstrated good agreement in the results. Numerous calculated investigations defining the possibility and efficiency of the BOR-60 operation as a minor-actinide burner were carried out. The various versions of the BOR-60 core with minor-actinides in the fuel and separate assemblies were considered. The influence of minor-actinides on the main neutron-physical characteristics and reactor safety was estimated.

The performed calculations show that the BOR-60 reactor possesses a high efficiency of the minor-actinide and plutonium burn-up (up to 37 kg/(TW*h)) that is comparable with properties of the actinide burner- reactors under design. The BOR-60 reactor can provide a homogeneous minor-actinide loading (minor-actinide addition to the standard fuel) to the core and heterogeneous loading (as separate assemblies-targets with a high minor-actinide fraction) to the first rows of a radial blanket that allows the optimum usage of the reactor and its characteristics.