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The behavior features of fuel elements with nitride fuel - theory and experiment

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The atomistic models of the swelling, creep, gas release, and nitride fuel decomposition are presented.
The models were verified on the results of nitride fuel elements irradiation in the Russian fast reactors BR-10, BOR-60 and BN-600.
At temperatures <1150 ℃ nitride fuel operate under athermal radiation processes that provide the best performance of the fuel element.
At high temperatures, a thermally activated processes leads to accelerated swelling, which is not compensated by the increased fission gas release.
Features of uranium mononitride define sensitivity of irradiation behavior to technology impurities - oxygen and carbon, including the transition temperature from athermal to thermally activated processes.
The calculations were done by the code NMUP-F (Nitride Mixed Uranium Plutonium Fuel), which combines the above mentioned atomistic models of radiation damage in the nitride fuel. Calculation of the cladding irradiation behavior was carried out by codes EDPA (Effective Displacement Per Atom) and VACS (Vacancy Activated Condensed System).
As a critical stage of fuel operation, the mechanical interaction with the cladding was considered. Under the operating conditions in developed fast reactors initial porosity of nitride fuel does not fully compensates swelling even at high temperatures.
The forecast of the marginal operating parameters of nitride fuel is done, depending on the design features of the fuel elements, the irradiation conditions, the cladding material, the structural parameters and content of impurities in fuel.
Based on calculations for fast reactor BN-1200 and BREST proposed the following design and materials for the "ideal" nitride fuel element of container type.
Fuel: density of pellet >95% of theoretical density, the oxygen content <1000 ppm and the carbon above stoichiometry (C + N) / (U + Pu) = 1 also less than 1000 ppm.
Cladding: ferritic-martensitic steel having tempered martensite structure with interlamellar distance of 0.1-0.5 microns.
Fuel element: diameter of 9-10 mm, the ratio of cladding thickness to diameter about of 1:20, the radial helium gap between the fuel and cladding approximately 0.1 mm. The ratio of free volume in the fuel element to the fuel volume is approximately 1: 1.
For the average fuel rod linear power of 40 kW/m (maximum 46 kW/m) this design provides burnup of nitride fuel up to 10 at.% (the equivalent burnup for oxide fuel about of 14 at. %) at a stress in the cladding less than 20 MPa.

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