The present status of research on dense nitride fuel for liquid-metal cooled fast reactors is examined. It is noted that within the framework of Proryv project nitride fuel is to be used in reactors with sodium (BN-1200) as well as lead coolant (BREST). Carbothermal synthesis of nitride from oxide powders has been chosen to fabricate the experimental fuel elements. Several experimental assemblies with mixed uranium-plutonium nitride fuel have been fabricated for tests in BOR-60 and BN-600. It is shown that the existing global experience in studying nitride fuel is insufficient for validating such fuel for use in BN-1200 and BREST. A complex program for computational-experimental validation of fuel elements is being implemented for validating the serviceability of fuel elements.

The general physical concept of fast reactors has undergone remarkable changes. The thesis that high breeding ratios are necessary no longer holds sway, but the thesis that a large reactivity excess on burnup, thereby securing the natural safety of the reactor, has stepped up. The natural safety requirement is formulated as a requirement to have a minimum reactivity excess in the core during an entire fuel run, which excludes the possibility of a nuclear accident with runaway on prompt neutrons. This requirement is best met in fast reactors with liquid-metal coolant, which solves the problem of guaranteed removal of the residual heat released during accidents with loss of first-loop integrity.

One way to improve the economics and safety of NPPs with fast reactors is to switch from mixed uranium-plutonium oxide fuel to high-density fuel with a high concentration of fissile isotopes.

Intensive research on dense forms of fuel for fast reactors with liquid-metal coolant is being performed in many countries. The qualitative characteristics presented in Table 1 show the promise of using metallic, nitride, and carbide fuel [1–4]. Investigation of such fuels with and without Np and Am are continuing in the USA, South Korea, and India, investigations of nitride fuel are continuing in the European Union and the USA (on a limited scale), and investigations of carbide fuel are continuing in France and India. The international fuel-improvement project as part of the Gen-IV project with the participation of the USA, the countries of the European Union, Japan, and South Korea anticipates that the final choice of the type of dense fuel will be made in 2015 and the serviceability of this fuel will be demonstrated starting in 2016 [1]. Carbide fuel is being studied in France as a promising dense fuel for a sodium-cooled fast reactor. The use of metallic uranium-plutonium-zirconium fuel is anticipated in designs of sodium-cooled fast reactors in the USA, South Korea, China, and India.

Nitride Fuel for the BREST and BN-1200 Reactors. As one can see from Table 1, the choice of fuel also depends on the type of liquid-metal coolant. If the sodium coolant shows good compatibility with metal and nitride fuel, then lead
coolant is compatible only with nitride fuel (there are no data on carbide fuel). In our country, both types of coolant are being studied as part of the Proryv project for future nuclear power – sodium for BN-1200 and lead for BREST. Mixed uranium-plutonium nitride fuel works in both types of reactors. For this reason, efforts are now being focused on studying it. The main requirements for fuel elements containing such fuel are presented in Table 2.

**Technology for Fabricating Nitride Fuel.** Mixed nitride fuel is produced mainly by the conventional pellet technology from the initial nitride powders. The two main methods of producing the initial powders on laboratory and experimental scales are carbothermal synthesis from oxides and hydrogenation-nitrogenation from metals. Both methods have disadvantages and advantages, so that the expediency of using one and the same method is determined mainly by the concept and stage of mastery of a closed fuel cycle.

Experimental BOR-60 fuel elements were fabricated by means of both technologies. Until recently, all fuel elements tested in research reactors were produced especially by the hydrogenation-nitrogenation (direct synthesis) technology. The powders were mixed in ball and vibratory mills, which ensure their activation in order to increase the sintering efficiency of uranium-plutonium nitrides.

A laboratory technology for producing nitride powders, obtained by means of hydrogenation–nitrogenation of metals of mixed uranium-plutonium nitride fuel in an AVS-150 vortex layer apparatus, was developed in 2002–2004 at the All-Russia Research Institute for Inorganic Materials (VNIINM). The technology was used to produce 4 kg of fuel for 15 experimental fuel elements with a lead sublayer for collapsible BOR-60 fuel assemblies. Two fuel assemblies, each containing seven fuel elements, were irradiated in the core to maximum burnup 4.3 and 5.5% h.a., respectively [5].

A laboratory technology was developed in 2008–2011 for the carbothermal synthesis of mixed uranium-plutonium mononitride from the initial oxides and fabrication of fuel pellets from it, likewise in AVS-150, making it possible to produce highly homogeneous powder mixtures in a short time. The high homogeneity is especially important for efficient solid-phase reactions with carbon, where the components must be in close contact with one another.

Carbothermal synthesis of nitride powders is now considered to be the method which from the industry standpoint is best understood. Its main advantage is the use of oxides as initial materials which are produced by operating enterprises.