SODIUM-COOLED FAST REACTORS IN RUSSIA: LOOKING BEYOND THE YEAR 2000

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Analysis of the state and prospects for the development of fast breeder reactors shows that while the same assessment is made of their strategic role as a real long-term source of energy for mankind on the global scale the views and approaches to the dates and speed of commercial introduction differ substantially. This is reflected in different immediate goals and tasks in national programs for nuclear power development and the investment policy of government agencies in regard to the design and construction of fast reactors in the world.

France. Until recently intensive scientific-research and test-design work on all aspects of fast reactors, including the EFR (European Fast Reactor) project. Such work on the EFR project has now been suspended. The decision to do so was evidently taken as a result of long shutdowns of the Phenix and Superphenix reactors.

Great Britain. Work on the EFR has been stopped as of 1993. The matter of shutting down and decommissioning PFR is under discussion.

Germany. The SNR-300 reactor, which was completed in 1986, will not be put into operation, according to a final decision. Work on the EFR has been suspended.

USA. The prospects for the commercial introduction of fast reactors is linked to the implementation of PRISM module reactor project, developed by General Electric. The decision on building it may be made within the next five years.

Japan. Construction and assembly of the Mondsii 250-MW(E) demonstration fast reactor have been completed. The physical startup is planned for October 1993. Development work is proceeding on a 600-MW(E) prototype fast reactor. The design work on the prototype reactor is being financed by the Federation of Electric Utilities.

Chinese People's Republic. Research and test-design work is under way on the CEFR project for a 25 MW(E) experimental fast reactor. It is to be built in this decade.

In our country, from the very beginning of the work the strategy for the development and introduction of fast reactors into the power industry was aimed at expanding the production of nuclear fuel and creating the possibility of nuclear power development unlimited by the uranium resources. The development and mastery of the first pilot BN-350 (loop design) and BN-600 (integrated design) reactors were intended to demonstrate the reliability and safety sodium-cooled fast reactors, to look for and optimize the structural layout and circuit designs of the reactor plant and its main components (reactor core, heat-exchange equipment, sodium pumps, control and safety rod actuators, fuel charging and discharging machines, safety system and sodium equipment). In connection with the optimistic plans for nuclear power development, the designers working on the next BN-800 and BN-1600 breeder-reactor projects concentrated their efforts on obtaining high breeding ratios BR ~ 1.5 and a doubling time T_{1/2} ~ 7-8 yr.

With the development slowing down since 1986 the situation in the nuclear power industry has changed fundamentally and economy of the uranium resources became the primary goal. Under the new conditions the prospects and potentialities of further development and practical use of fast reactors are determined by their safety level and economy. At this stage the main goal set for design work on fast reactors was to obtain a high, subsequently maximum attainable, degree of safety and economic competitiveness with light-water reactors. Experience from the operation of pilot BN-350 and BN-600 reactors gave fast-reactor designers a real basis for reaching the goals set.

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The accrued operating time of BR-10, BOR-60, BN-350, and BN-600 fast reactors is more than 80 reactor-yrs. The experience gained from the operation of the BN-600 in a power system is the most important for fast reactors. All of the above-mentioned reactors exhibited a high degree of operating safety. Negative power and temperature reactivity coefficients ensure that the reactors are self-regulating. The field of heat release in the reactor core is stable and the excess reactivity is low. The reactor is simple to control. Low sodium pressure and no appreciable corrosion ensure that the loops are completely leakproof. There are no small leaks of radioactive sodium in the reactors. Despite some difficulties due to the novelty of technical problems, the reliability is high. The average installed-capacity utilization factor (ICUF) of the BN-600 was 71% in ten years of operation (1982-1991), 74% in the period 1983-1989. Thus, in regard to the main operating indicator, characterizing the maturity of reactor technology, the ICUF reached in the pilot BN-600 is typical of commercial reactors (Table 1).

Good operating indicators are ensured primarily by the reliable operation of the main equipment of the reactor (core, pumps of the primary and secondary loops, intermediate heat exchangers, fuel charging and discharging machines, fuel assemblies). Steam generators, which caused the greatest operating difficulties in the first stage because of small leaks between loops, were the key problem. The modular design of the steam generators of BN-600 with reliable localization of the small leaks and the possibility of disconnecting and repairing the leaking sections without shutting down the reactor ensured minimum losses of electricity generation because of malfunctions of steam generators. The intermediate sodium loop is a reliable barrier separating the radioactive sodium of the first loop from the steam generators; leaks of a steam generator thus are not radiation accidents and the repairs of steam generators is not restricted by radiation conditions.

The principal advantage of a fast reactor is the minimum environmental impact of radiation. The average discharge of gas activity of the BN-600 into the atmosphere in 1980-1989 was 9.5 Ci/day, compared to the 500 Ci/day allowed by existing standards. After modernization of the reactor core the discharge of activity was reduced to 1.3 Ci/day. The discharges into the air contain inert radioactive gases, namely, xenon, krypton, and argon. These gases pose no danger to the population since they have a short half-life and do not enter into chemical compounds with other substances. The long-lived aerosols (137Cs, 90Sr) in the discharges are less than 1% of the allowable level. The discharges do not contain radiatively dangerous 131I because it is held very effectively by sodium.

The danger of sodium burning in leaks proved to be exaggerated. Prolonged operating experience showed that sodium leaks are blocked very easily by technical means (protective jackets, an inert medium, passive technical fire extinguishing agents, and pouring the sodium off into emergency containers and self-extinction of the sodium in them). The experience gained confirmed that fast reactors have a high degree of self-protection. No fundamental difficulties associated with reactor physics, the functioning of the equipment, the technology, and materials research problems, which could have hindered their improvement, did not arise during operation.

The successful experience from operating BN-600 raised the question of implementing projects for improving nuclear power plants with fast reactors. The BN-600 project was based on the primary equipment, tested in prolonged operation of the BN-600; the thermal capacity of the reactor was increased by nearly 50% with the same reactor vessel dimensions, thus making it possible to ensure that the unit had a (net) electrical capacity of 800 MW. After 1986 the BN-600 project was improved to enhance the safety substantially. The main change, ensuring a qualitatively new level of safety, was the elimination of the positive sodium void reactivity effect. A new reactor core design was developed for this purpose. Moreover, passive means for affecting the reactivity were introduced, being actuated when the sodium flow in the primary loop through the reactor core decreases or ceases.

It was decided in 1992 to complete the development and licensing of projects for the South Ural Nuclear Power Plant and the fourth power unit of the Beloyarsk Plant with a BN-800 reactor for further construction. The BN-800 will operate in a uranium-plutonium oxide cycle and industrial facilities to fabricate fuel assemblies with such fuel are being built at the "Mayak" Industrial Amalgamation.

### TABLE 1. ICUF of Russian Nuclear Power Plants

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<td>Average for all plants</td>
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