FAST REACTOR BREST-300

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Abstract

This paper describes the nearest future of nuclear power engineering in terms of fast reactor - BREST-300. The article shows its design, characteristics and benefits of fast reactors. Even modern reactors with slow neutrons have high energy rates, but there are some problems such as rarity of Uranium -235 and large amounts of waste. The Russian development of BREST-300 is able to solve some of the problems.

Key words: BREST-300, fast reactor(FR), loop, fuel assembly (FA), closed nuclear fuel cycle (CFC), thermal power, electric power, fuel lifetime.

Introduction

Future large-scale nuclear power (NP) based on FR in a CFC, can arrest the growth of fossil fuel consumption, provide the bulk of electricity production increase, and "… resolve the problems of energy supply for sustainable human development, non-proliferation of nuclear weapons and environmental improvement of the planet…" [8] stated Russian President V.V. Putin at the UN Millennium Summit in 2000.

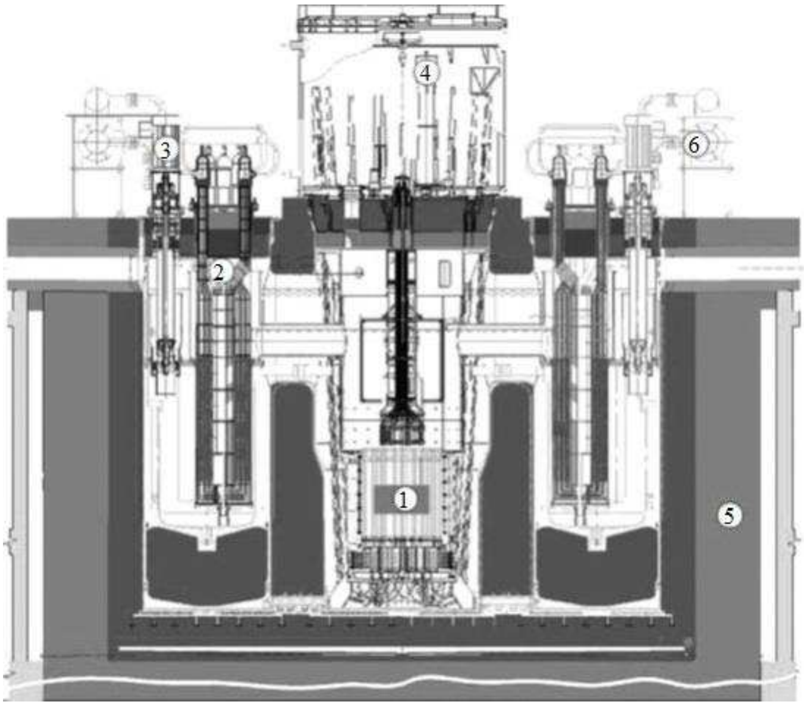
Nuclear power will not be socially acceptable unless it gains high safety and security, interpreted broadly as:

- freedom from the constraints of fuel resources;
- impossibility of severe accidents with uncontrollable power growth, loss of cooling, fires and explosions, accompanied by radioactive and toxic releases at a level requiring public evacuation;
- technological support of the non-proliferation regime;
- environmentally safe closing of the fuel cycle and final waste disposal without upsetting the natural radiation equilibrium;
- ability to compete economically with alternative energy sources. [5]

Thanks to contributions made by a number of institutes and research centers, all the above requirements are met by the innovative nuclear technology under development at NIKIET now. This technology relies on the concept of BREST – a naturally safe FR with nitride fuel, lead coolant and a special onsite closed fuel cycle. [5]

Design of a Nuclear Power Plant with a BREST-300 Reactor System

The thermal scheme is a two-loop scheme, the first loop containing lead with the required purity and the second loop containing water–steam with supercritical parameters. [3] The second loop is nonradioactive, it consists of a feed-water system, steam generators, the main steam pipes and a single turbine unit. The water chemistry in the second loop, adopted on HPP blocks with supercritical pressure, is a neutral-oxygen regime with no de-aerator. [4] The K-300-240-3 serially produced turbine facility developed by the Leningrad Metal Works contains a steam turbine with systems for rotating the shaft, lubrication, regulation, and hydraulic lift of the rotors, and others. In contrast to existing designs of nuclear power plants, the second loop is not required to remove heat in an emergency situation. [4] The buildings of the main loop are able to withstand an earthquake, they were designed taking account of the norms for designing earthquake-resistant nuclear power plants. For design purposes, an earthquake of magnitude 6 was assumed and the maximum earthquake was taken to be magnitude 7 on the MSK-64 scale. [1] To ensure reliable operation of the structures, the spatial system of the reactor buildings is designed in monolithic reinforced concrete. The building was designed to be symmetric with dimensions in the plane 65 *74 m, separated by crossed vertical bearing diaphragms to decrease inertial seismic forces. [2]



BREST-300 reactor: 1) core; 2) steam generator; 3) pump; 4) reloading machine; 5) shaft; 6) cooldown system. [2]

Characteristics of BREST-300 [9]

Thermal power, MW	700
Electric power, MW	300
Fuel assembly design	Shrouded
Number of fuel assemblies	199
Core diameter, mm	2650
Core height, mm	1100
Fuel rod diameter, mm	9.7; 10.5
Fuel rod pitch, mm	13.0
Core fuel	(U+Pu+MA)N
Fuel inventory, (U+Pu+MA)N, t h.m.	24.1

Mass of (Pu)/ (Pu239+Pu241), t	3.1/2.2
Fuel lifetime, eff.days	1800
Cycle-averaged CBR	~1.05
Average/max. fuel burnup, MW·d./kg	53/84
Inlet/outlet lead temperature, °C	420/540
Maximum fuel cladding temperature,°C	650
Water-Vapor temperature at SG inlet/outlet, °C	340/505
Pressure at SG outlet, MPa	18
Design life, years	30

Benefits of BREST

- natural radiation safety from any possible accidents on internal and external reasons, including sabotage, not requiring evacuation; [6]
- long-term (almost unlimited in time) ensuring fuel resources through the effective use of natural uranium; [6]
- U blankets are excluded (replaced by Pb) to rule out production of weapons-grade Pu; [5]
- environmentally friendly energy production and disposal of radioactive waste without upsetting the natural radiation balance; [6]
- economic competitiveness due to natural plant safety and fuel cycle technologies, rejection of complex engineering systems security. [6]

Natural radiation safety is provided by:

- using of high boiling (T = 2024 K), radiation-resistant and low-activated lead coolant which do not react with water and air, which prevents fires, chemical and thermal explosions in the event of depressurization of contour, steam leakages and any temperature coolant; [6]
- use of jacketless FAs with wide grid fuel rods in the active zone of moderate power (maximum ~ 200 M*W/m^3), excluding loss of heat removal at the local overlap of flow area in FAs providing a high level of natural circulation of coolant; [6]
- choice of the design of active zone with lead reflector the composition and geometry of which provide a complete reproduction of fuel (ACC-1); [6]
- use of passive protection systems of direct-acting reactor which regulates flow rate and temperature of the coolant at the inlet and outlet of the active zone; [7]
- a passive system of external air emergency cooling of reactor through the body; [6]
- high heat storage capacity of the lead circuit. [6]

Competitiveness

- Thanks to the simpler design of the facility, its safety systems and to efficient utilisation of nuclear fuel and generated heat, a plant with a BREST-type reactor is expected to be economically competitive.
- Low lead pressure in the circuit allows using an integral configuration of the circuit components in a concrete pool, which was tentatively shown to reduce the construction costs.

- On-site fuel cycle arrangement is also likely to be economically beneficial owing to the shorter out-of-pile cooling and transportation time, which will eventually lead to a reduction in the recycled fuel quantity – one of the greater contributors to the fuel cycle costs.

Conclusion

The BREST-300 development efforts carried out to pave the way for commercial reactors of this type and thereby to lay a foundation for large-scale nuclear power, show that such reactors can provide: [10]

- radical improvement of safety with elimination of the most dangerous radiation accidents by combining the fast reactor's properties and its components with features of natural safety;
- unlimited fuel resources and independence from U mining.
- reduction of the proliferation risk;
- conclusive solution of the radioactive waste problem;
- ability to compete with other types of power generation. [5]

References

1. V.V. Orlov, V.S. Smirnov, A.I. Filin, et al., “Deterministic safety of BREST reactors,” in: 11th International Conference on Nuclear Technology, Tokyo, Japan, April 20–23, 2003, ICONE11-36415.
2. A. G. Glazov, P. P. Polyéktov, V. F. Leont’ev, and R. S. Karimov, “Fuel cycle for BREST reactors. Solution of RAO and nonproliferation problems,” ibid., ICONE11-36405.
3. V. S. Smirnov, A. V. Lopatkin, I. P. Matvienko, et al., “Experimental and computational validation of the neutron-physical characteristics of a BREST-OD-300 reactor,” ibid., ICONE11-36412.
4. A.I. Filin, B.B. Kubintsev, Yu.V. Nesterov, et al., “Main technical solutions for the second loop for a nuclear power plant with a BREST-OD-300 reactor system,” in: Proceedings of TsKTI on the Improvement of the Electrical Equipment, Energy Technologies, Thermal Schemes, and Operating Regimes of Power Plants, St. Petersburg (2002), pp. 15–18.
5. V.S. Smirnov “Lead-Cooled Fast Reactor BREST – Project Status and Prospects” 2012
6. V.I. Boiko, V.V. Sidlovskiy, V.N. Mescheryakov, I.V. Shamanin, F.P. Koshelev, D.G. Demyanyuk: “Perspective nuclear fuel cycles and reactors of new generation”, Tomsk Polytechnic University. -Tomsk: Publishing House of Tomsk Polytechnic University, 2009. - 518.
7. I.N.Bekman "Nuclear Industry" Lecture Course, Lecture 14. "Advanced Nuclear Reactors".
8. Statement by Russian President Vladimir Putin at the Millennium Summit of the United Nations (in Russian) / / International Law. - 2000.
9. Атомные электростанции высокой безопасности и экономичности с быстрым реактором со свинцовым теплоносителем БРЕСТ с пристанционным топливным циклом. http://www.nikiet.ru/index.php?option=com_content&view=article&id=101%3A2011-03-18-13-33-18&catid=3&Itemid=4
10. БРЕСТ: быстрый реактор со свинцовым теплоносителем и пристанционным топливным циклом. http://www.atomic-energy.ru/technology/36000