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Development of Technologies for the Fusion-Fission Hybrid Systems

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Environmentally acceptable nuclear energy is an important component of global energy today. However, the difficulties associated with the production of nuclear fuel, reprocessing and disposal of radioactive waste from fission reactors limit its development. The integration of technologies can ensure long-term and sustainable development of the world energy system. One of the most promising ways to solve these problems are fusion neutron sources (FNS) using the fusion reaction of heavy hydrogen isotopes: D and T. The relevance of the development of a hybrid fusion-fission reactor system lies in the possibility of using thermonuclear neutron fluxes to produce fuel nuclides, for example U-233.

The project of creating a hybrid installation is aimed at achieving long-pulse operating modes with a load on the first wall of up to ~ 0.2 MW/m2 of neutrons with an energy of 14 MeV and neutron fluence during the life cycle of the installation of ~ 2 (MW x year)/m2 (10 years of continuous operation).

Within the framework of hybrid technologies being developed by the Kurchatov Institute Research Center, the current tasks are: development of a project for an experimental compact neutron source (CNS), including the definition of technological schemes of the main installation systems, as well as the development of prototypes of various variants of the nuclear blanket, demonstration of the possibility of obtaining the isotope U-233 from the natural isotope Th-232. In connection with the expected results of experiments on the tokamak T-15MD, it seems advisable to consider the possibility of creating the CNS with the scale of this installation.

The design goals for the period 2021-2024 are focused on the development of new plasma modeling tools and operational scenarios, improving the performance of auxiliary systems and integrating devices that implement upgraded and new technical solutions. These include the first wall, divertor, NBI, fuel filling and pumping, ECR heating and current drive, heat transfer, fusion and nuclear fuel cycles, lithium technologies.

The conducted economic assessments have shown that the cost of fissile nuclides obtained because of processing solid-state spent nuclear fuel and fuel from the molten salt layer is comparable. However, it should be borne in mind that in a hybrid system with suppressed fission, fewer minor actinides and radioactive waste are formed than in nuclear reactors. Therefore, it seems expectable that the cost of fissionable nuclides produced using a hybrid blanket can potentially increase economic efficiency.

A comparative analysis of the radiation damage to the first wall of the hybrid installation was carried out when replacing the beryllium coating with a tungsten one. The results showed that tungsten is the best material for the first wall. However, it is necessary to take into account its increased fragility with a significant time exposure to high-energy neutrons.

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