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Soliton-like Regime of Neutron Transport in a Multiplying Medium. Physical Ground of Traveling Wave Reactor

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An essentially nonlinear process of neutron transport in a multiplying medium, such as fuel of a nuclear reactor, under certain conditions leads to the realization of a self-sustaining regime of a propagating chain nuclear reaction in the form of a traveling wave. This phenomenon is called nuclear deflagration or slow nuclear burning. The possibility, as well as the criterion for the appearance of such a regime in a fast reactor-breeder, was first demonstrated by Lev Feoktistov in 1988 [1] by means of analytical solving the diffusion equation for neutron transport together with a set of burn-up equations for nuclear transformations, that make this problem nonlinear.

The most important distinctive feature of the self-sustaining regime of a nuclear burning wave (NBW) is the lack of the need for operational criticality control of such a reactor, since its critical state is maintained automatically. This practically eliminates a role of so called "human factor" in reactor control and, therefore, the risk of this type of accident. Moreover, a special mechanism of the negative feedback inherent in this reactor ensures its automatic return to a critical state, even with external intervention, bringing the reactor out of the stationary mode in one or the other direction. In addition, either natural (or even depleted) uranium and thorium or spent fuel from conventional reactors can be used as a fuel in such reactor that solves the problem of providing mankind with energy resources for thousands of years.

Significant contribution to the development of this concept was made also E. Teller [2], H. Sekimoto [3], and others. The ambitious plan for the practical realization of the Traveling Wave Reactor in the close future has announced by the firm TerraPower created with financial support from Bill Gates [4].

A brief review of the progress in development of the NBW reactor concept obtained over the past 10 years, including the original results of the authors, is presented in this paper. The main attention in our studies [5-7] was concentrated on studying the stability of the NBW regime, especially at transient processes in the reactor during its start-up, forced shutdown and subsequent restart. The impressive reactor stability against different types of external actions demonstrates its intrinsic safety property.

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