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NUCLEAR POWER STATIONS

Emergency Cooling Down of Fast-Neutron Reactors by Natural Convection (a Review)

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Abstract—Various methods for emergency cooling down of fast-neutron reactors by natural convection are discussed. The effectiveness of using natural convection for these purposes is demonstrated. The operating principles of different passive decay heat removal systems intended for cooling down a reactor are explained. Experimental investigations carried out in Russia for substantiating the removal of heat in cooling down fast-neutron reactors are described. These investigations include experimental works on studying thermal hydraulics in small-scale simulation facilities containing the characteristic components of a reactor (reactor core elements, above-core structure, immersed and intermediate heat exchangers, pumps, etc.). It is pointed out that a system that uses leaks of coolant between fuel assemblies holds promise for fast-neutron reactor cooldown purposes. Foreign investigations on this problem area are considered with making special emphasis on the RAMONA and NEPTUN water models. A conclusion is drawn about the possibility of using natural convection as the main method for passively removing heat in cooling down fast-neutron reactors, which is confirmed experimentally both in Russia and abroad.

Keywords: natural convection, emergency cooling down, fast-neutron reactor, passive decay heat removal system, experimental investigations, thermal hydraulics, model, similarity criterion, temperature, heat exchanger

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One of the main problems that have to be solved in creating safe nuclear power facilities is to develop and construct a high-efficient and reliable system for removing decay heat during emergency cooling down of fast-neutron reactors. A passive heat removal system that uses natural convection as the main method of heat removal can serve as such system, which is implemented by inserting immersed heat exchangers into the fast reactor vessel's space. Such a system optimally suits to the safety requirements that have to be complied with in cooling down reactors; it does not impose any limitations on the power capacities of these reactors (fast-neutron power-generating reactors are dealt with); it has low inertia; it is relatively inexpensive, etc. Further development of fast reactors is connected with substantiating the operation principles of this system.

The aim of this paper is to show the effectiveness of applying natural circulation for heat removal in using different emergency reactor cooldown methods. The investigations performed by the authors on this problem that were reported in [1–7] were laid as a basis of the present work. Passive systems for emergency cooling down of the cores of thermal-neutron reactors are discussed, e.g., in [8–10].

CHARACTERIZATION OF DIFFERENT METHODS FOR EMERGENCY COOLING DOWN OF FAST REACTORS

The decay heat releasing in a reactor can be removed during its cooldown process either in the usual way, i.e., by installing an intermediate heat exchanger, steam generator, and turbine condenser (which can be conditionally called a "horizontal" heat removal) or, if the operation of a steam turbine unit is impossible, by connecting a direct reactor cooling safety system (DRC) that removes heat to the atmospheric air (which can be conditionally called a "vertical" heat removal), the latter being a passive method of heat removal (Fig. 1).

There are a few auxiliary passive decay heat removal systems intended for use to cool down a reactor.

The direct reactor auxiliary cooling system (DRACS) allows heat to be removed from the sodium circulating in the reactor's primary coolant circuit by natural convection in immersed sodium-to-sodium heat exchangers called decay heat exchangers (DHXs). The heat absorbed in these heat exchangers, which are placed in the fast reactor's hot chamber, is then transferred to air by means of sodium–air heat exchangers (AHXs) arranged at a height of approximately 30–40 m above the immersed heat exchangers.