
HEAT AND MASS TRANSFER AND PROPERTIES OF WORKING FLUIDS AND MATERIALS

Investigations of Coolant Stratification and Temperature Pulsations in Nuclear Power Installations

D. G. Zaryugin, S. G. Kolyakin, A. N. Opanasenko, and A. P. Sorokin

*State Scientific Center of the Russian Federation—the Energy Physics Institute,
pl. Bondarenko 1, Obninsk, Kaluga oblast, 249033 Russia*

Abstract—Specific features of stratified flows are considered taking fast-neutron reactors as an example, the possibilities of scale-wise simulation of such flows are discussed, and some results obtained from experimental and numerical investigations of flows in mixing chambers and pipelines are presented. The mixing of sodium jets in the upper chamber at the outlet from the fast-neutron reactor core is analyzed.

Keywords: fast-neutron reactor, upper chamber, temperature stratification, recirculation zone, temperature pulsations, computation codes, verification

DOI: 10.1134/S0040601513030051

The experience gained from operation of the BN-600 reactor, the results of special measurements performed in the reactor, and the data of experimental investigations carried out on models have shown that temperature stratification of coolant exists in the elements of a reactor vessel containing a large volume of coolant. The coolant temperature stratification processes that are not stipulated by the design documents cardinally alter the coolant motion structure and its temperature conditions; they also lead to the occurrence of stagnant zones and recirculation formations with high gradients and pulsations of temperature at the interface boundaries between isothermal zones. The thermal fatigue of material caused by the gradients and pulsations of temperature in a stratified flow shortens the lifetime of in-vessel equipment [1–3].

Temperature stratification of coolant also has an essential effect on the reactor's nuclear-physical characteristics, on the physico-chemical interaction between the coolant and structural materials, and on the oxide sedimentation processes in the cold stagnant zones of the reactor vessel. It also generates the need to carry out work for substantiating the layout of regular sensors for control purposes and the placement of cold filters for trapping oxides in the vessel. The capacities of modern computation codes allow researchers to obtain only an average temperature distribution pattern in the flow of coolant, whereas the pulsation characteristics of temperature are as a rule not predicted by calculations.

One of the tasks imposed on the emergency cooldown system (ECS) used in the modernized model of a fast-neutron reactor's vessel is to study the specific features of thermal-hydraulic processes occurring in the reactor vessel's nonisothermal volume in different operating modes of the installation. The investigations must be carried out using a combined numerical-and-experimental approach; i.e., they must involve measurements of not only averaged, but also local pulsation characteristics of temperature and velocity and their distributions, and the applied computation codes must in the subsequent include calculations of thermal stresses in the material of reactor equipment.

Local hot spots occurring during deformations of fuel rod spacer grids, blocked parts of fuel assembly sections, and other factors may serve as sources of temperature nonuniformity above the heads of fuel assemblies (FAs) in the upper chamber of a fast-neutron reactor. Investigations of heat transfer are in this case concerned with monitoring the coolant temperature above the core and fluctuations of sodium temperature, which also affect the strength of constructions under steady conditions of reactor operation.

INVESTIGATIONS OF TEMPERATURE NONUNIFORMITIES IN THE UPPER CHAMBER ON AN INTEGRAL WATER MODEL OF THE REACTOR VESSEL

Integral models made on a certain scale and simulating operation of the main components of a real