NATURE OF HEAT EXCHANGE AND HYDRAULIC RESISTANCE UNDER CONDITIONS OF FORCED MOVEMENT OF A LIQUID AT SUPERCRITICAL PRESSURE

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The results are presented of an experimental study of hydraulic resistance and high-frequency pulsations in pressure arising during the process of heat exchange at supercritical pressure of n-heptane as a function of wall temperature, flow rate, and length of the working channel.

There are a number of works published in the current literature devoted to a study of heat exchange at supercritical parameters under conditions of forced fluid movement. The results of the published works do not present a uniform picture. One author observed a system in which the heat-exchange coefficients were considerably higher than those calculated from the known equations of convective heat exchange [1-3], others observed systems with poorer heat exchange. The given deviations were explained either by the effect on the heat exchange of a change in physical properties [4] or by the effect of free convection [5]. The effect of free convection on the decrease in heat exchange in the supercritical region was persuasively confirmed experimentally [6]. It must be assumed that the effect of the natural convection will develop for the most part at low current velocities.

The results of an experimental study of the heat-exchange process during forced movement of n-heptane over a wide range of current velocities (5-30 m/sec) at supercritical pressure (P/P_{cr} = 1.45) are presented in this article. The joint consideration of heat exchange, hydraulic resistance, and high-frequency pressure pulsations arising during the heat-exchange process allows one to show the presence of principles demonstrating that the mechanism of heat exchange at supercritical parameters as a function of the hydrodynamics of the current has a varied nature.

The experiments were conducted on 0Kh18N10T steel tubes 2.02/2.52 mm in diameter (the length of the heated section was 40 and 100 mm), and on tubes 2.4/3.0 mm in diameter (length of heated section 40 mm). Measurements of the characteristics of the heat exchange, hydraulic resistance in the working section, and high-frequency pressure pulsations arising during the heat-exchange process were conducted synchronously during the experiments.

The design of the apparatus is described in [7]. Measurement of the hydraulic resistance was conducted using DM-6 and EPID instruments with maximum scales of 1, 2.5, and 6.3 atm, as well as a U-shaped mercury differential manometer. The experiments were conducted both with rising and dropping movement of the liquid.

The experimental data obtained on the 2.02/2.52 mm tube are presented in Fig. 1 in the form of the dependence of the wall temperature on the heat flux t_{w} = f(q) and of the hydraulic resistance on the heat flux in relative coordinates \( \Delta P/\Delta P_{0} = f(q/q_{m}) \) for the same experiments.

As seen from Fig. 1, at low current velocities (5 m/sec) in the region of wall temperatures above \( t_{m} \) the heat exchange is characterized by a sharp increase in hydraulic resistance \( \Delta P \sim q^{2-4} \) and an insignificant improvement in heat exchange. The increase in resistance can evidently not be explained by increased mass exchange between the boundary layer and center of the current. In these experiments...
Fig. 1. Dependence of wall temperature (a, c) and hydraulic resistance (b, d) on heat flux (d = 2.02/2.52 mm, $t_2 = 20^\circ C$): a, b) $l_h = 40$ mm; c, d) $l_h = 100$ mm; 1) 5; 2) 10; 3) 15; 4) 30 m/sec; $t_w$, °C; q, W/m².