PSEUDOBOILING AND HEAT TRANSFER IN A TURBULENT FLOW

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Experimental data characterizing the onset of pseudoboiling in relation to flow rate, pressure, and tube diameter are presented for diisopropylcyclohexane (DICH).

Many investigators have noted that, under certain conditions at supercritical pressures, heat transfer is sharply improved [1–4]. The same plateau T_w = = const as in heat transfer with surface boiling at subcritical pressures is formed on the curves expressing the dependence of the wall temperature T_w on heat flux q.

We have already established that heat transfer with pseudoboiling at $p > p_{cr}$ and heat transfer with surface boiling at $p < p_{cr}$ are always accompanied by pressure oscillations with the same amplitude-frequency characteristics [5]. Subsequent investigation of diisopropylcyclohexane (DICH) (p_{cr} = 1.96 MN/m^2, T_{cr} = 650° K) has established that the transition from ordinary convective heat transfer to pseudoboiling strongly depends on the flow rate, pressure, and channel diameter. The experiments were conducted on the heat-exchange apparatus described in [5] with 1Cr18Ni10Ti stainless-steel tubes 0.8, 1.6, and 2.3 mm in diameter, wall thickness 0.2 mm, length (for calculation purposes) 30 mm.

The pseudoboiling conditions were investigated in the range of flow rates 2–50 m/sec at pressures of 2.9, 3.9, 4.4, and 4.9 MN/m^2. In all the experiments, the temperature of the DICH was much less than T_{cr} and varied in the range 290–320° K.

The experimental data in Fig. 1 show the effect of the flow velocity on pseudoboiling. At $w \gtrsim 10$ m/sec, the transition from ordinary convective heat transfer to pseudoboiling was characterized by a smooth change of wall temperature. At lower velocities, the onset of pseudoboiling was accompanied by an abrupt drop in wall temperature. At w = 2 m/sec, pseudoboiling did not occur even at T_w = 1250° K.

From the data of Fig. 2 it follows that, as the velocity increases, the value of T_w at which pseudoboiling occurs falls, while, as q increases, T_w asymptotically approaches a constant value. With increase in reduced pressure p/p_{cr}, the T_w characterizing transition to pseudoboiling rises. The nature of the $T_w = \varphi(q)$ relation is the same for all the pressures investigated.

Figure 3 illustrates the effect of varying the tube diameter. These data show that, other things being equal, as the tube diameter increases, the T_w corresponding to the onset of pseudoboiling rises.

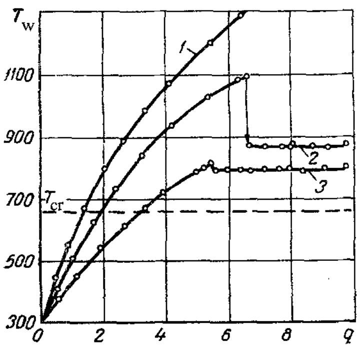

Fig. 1. Variation of the relation $T_w = \varphi(q)$ with velocity for heat transfer with DICH (pressure 4.41 MN/m^2; T_w in °K, q in MW/ /m^2): 1) w = 2; 2) 4; 3) 10 m/sec.

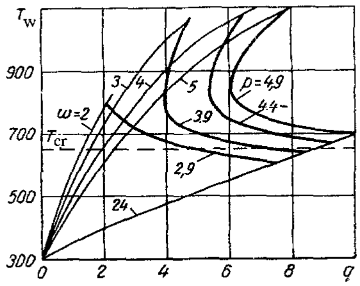

Fig. 2. Temperature of the onset of pseudoboiling (°K) (high-frequency oscillations) as a function of the heat flux (MW/m^2) at various DICH flow velocities (m/sec) and pressures (MN/m^2).

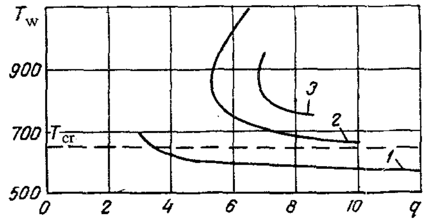

Fig. 3. Temperature (°K) of onset of pseudoboiling (high-frequency oscillations) as a function of heat flux (MW/m^2) for tubes of various diameter (pressure 4.41 MN/m^2): 1) d = 0.8; 2) 1.6; 3) 2.3 mm.

From our investigation, we conclude that pseudo-boiling is characteristic of heat transfer under the conditions $p > p_{cr}$ and $T_l < T_{cr} < T_w$, the wall temperature being the higher, the higher the pressure, the greater the tube diameter and the lower the flow velocity of the liquid.

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