NOTATION

p	is the static pressure;
ρ	is the density;
u	is the mean velocity over the channel section;
v_w	is the radial velocity at the wall;
L	is the length of the channel section;
D	is the channel diameter;
d	is the diameter of apertures in the porous wall;
ε_f	is the channel porosity;
x	is the coordinate;
$X = x/L$	is the relative coordinate along the channel;
ξ_0	is the friction factor for flow in a channel with solid walls;
Re	is the Reynolds number.

Indices

e	is the evaporation section;
a	is the adiabatic section;
c	is the condensation section;
0	are the values of the parameters at the entrance to the condensation section.

LITERATURE CITED

1. R. M. Olson and E. R. Ekkert, Prikl. Mekh., 88, No. 1 (1966).
2. V. S. Mikhailov, A. M. Krapivin, P. I. Bystrov, and G. I. Pokandyuk, Teplofiz. Vys. Temp., 13, No. 2 (1975).
3. E. N. Ambartsumyan, A. I. Leont'ev, and V. G. Puzach, in: Proceedings of the First International Conference on Heat Pipes, Stuttgart (1973).

HEAT TRANSFER WITH BOILING OF A THIN WATER FILM ON A TEFLON SURFACE

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An experimental investigation has been made of heat transfer with boiling of a thin water film on a horizontal heat-generating surface, made of Teflon-4.

Contemporary literature has practically no information on heat transfer with boiling and break-up of thin liquid films on poorly wetted heater surfaces, which might serve as a guideline for the present investigation.

Tests were made on a circular horizontal surface of diameter 28 mm (the end of a copper thermal wedge) to which (with type PU-2 OFTU-G0029004 adhesive) a thin Teflon film (Teflon -4) was attached. The total thickness of the film and the polymerized substrate of adhesive, measured by means of a digital indicator with resolution of 0.01 mm, was 0.09 mm. This liquid-layer thickness above the heat-generating surface was maintained by influx from the periphery of liquid heated to the saturation temperature and was monitored by a needle contact method to within ±0.01 mm. The heat-flux density and the temperature of the heat-generating surface, allowing for the temperature drop in the Teflon layer, were determined from the temperature gradient along the wedge body. The tests were carried out in distilled water at atmospheric pressure in the heat-flux range 20-300 kW/m^2. The Teflon surface was prepared using fine emery paper.

When water boils in a large vessel (liquid-layer thickness not less than 100 mm), the heat-emission coefficients are practically the same as the heat-emission coefficients on the metallic surfaces of a heater. One should note especially that, in a large vessel, boiling is observed at individual centers for very low heat-flux values (on the order of 3 kW/m^2), and correspondingly, at low excess temperatures of the heat-generating surface of 1.5-2°C.

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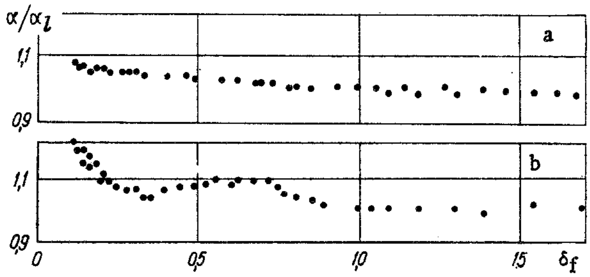

Fig. 1. Relative heat-transfer intensity as a function of water film thickness (mm) on a Teflon surface at atmospheric pressure: a) q = 116 kW/m^2; b) 23 kW/m^2.

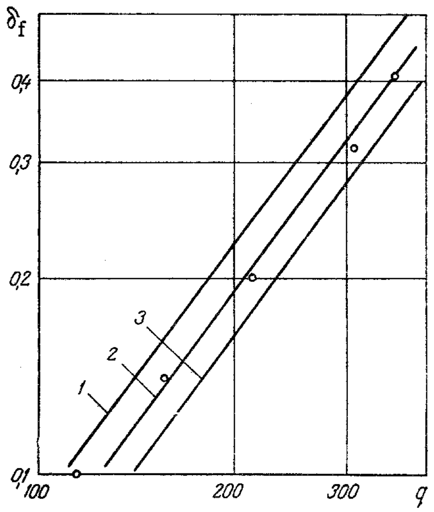

Fig. 2. Critical breakdown thickness (mm) of a boiling-water film as a function of heat flux (kW/m^2): 1) stainless steel; 2) Teflon-4; 3) type PSr-45 silver alloy.

At heat-flux levels of 100 kW/m^2 and below (Fig. 1) there is some increase in the heat-generating intensity as the liquid is reduced. Here the picture is qualitatively almost the same as was seen previously on the copper-heater surface. The difference is that for a layer thickness of more than 1 mm there is no reduction in heat transfer, such as is always observed on a copper-heater surface. The reason is that on the Teflon surface, which has a broader size spectrum of nonwetted cavities to act as vaporization centers compared with copper, a decrease in the coefficient of growth of vapor bubbles in a volume [1] is compensated by greater activity on the part of the existing vaporization centers.

An increase in heat-transfer coefficients for film thicknesses less than 1 mm on Teflon, as on the copper surfaces, arises from the fact that at roughly this thickness the transfer of heat by conduction and convection in the gaps between vaporization centers begins to increase appreciably. This is confirmed, in particular, by the fact that the slope of the curve $\alpha = f(\delta_{film})$ (Fig. 1b) for thicknesses 0.7-1 mm is the same as that of the curve $\lambda/\delta_{film} = f(\delta_{film})$.

The drop α for thicknesses of less than 0.6 mm is linked to the appearance of small dry spots in the film, and additionally, to some of the active vaporization centers ceasing to function, due to the reduction in the liquid level. For film thicknesses less than 0.2-0.3 mm the heat transfer by conduction increases sharply and compensates for the reduction in α observed earlier.

At large heat-flux values (Fig. 1a) the drop is α is absent, since in this case suppression of some of the active vaporization centers does not affect the heat-transfer intensity as markedly, because of their abundance on the heater surface.

For heat-flux levels of more than 100 kW/m^2, the heat-transfer intensity does not differ very much from the value for a large volume, as the height of the liquid layer is reduced. The observed slight drop in heat-transfer coefficient (up to 5%) for thicknesses close to the breakdown level is due to the appearance in the thin film of fine dry spots at the sites of the active centers, which are wetted afresh by the surrounding liquid at a later time.

Figure 2 shows critical thicknesses for breakdown of a thin boiling-water film as a function of heat-flux density at atmospheric pressure for surface of stainless steel, Teflon, and a surface covered with a layer of type PSr-45 silver alloy. As can be seen in Fig. 2, the boiling-water film, contrary to expectation, is very stable on the Teflon surface, in spite of the poor wetting under isothermal conditions.

The contact angle in wetting of a dry spot (at the boundary of the liquid-wall interface) cannot be equal, under intense heat-transfer conditions, to the static wetting angle, because of the practically instantaneous evaporation of a very thin liquid film near the dry-spot boundary. This angle depends mainly on the heat flux and the film thickness, although one cannot completely exclude the influence of the wetted surface under isothermal conditions.

The influence of the surface material is most closely linked with the different number of active vaporization centers under the same heat-flux condition. The larger the number, the smaller the average separation bubble diameter, i.e., the smaller the size of the dry spot formed at the site of a disintegrating bubble, and therefore, the more easily it is rewetted. In addition, the greater the action of centers on the surface, the larger the liquid waves on the film surface, which also improves the wetting of dry spots.

Of the three heat-transfer surface materials compared, the smallest number of centers is observed on the stainless steel surface. The number of active centers was greater for the Teflon surface than for the silver alloy surface, however, in this case the poor wetting of Teflon plays some part, which also accounts for the large stability of the film on the surface of type PSr-45 alloy.

Thus, a Teflon surface differs very little from metallic heater surfaces under conditions with heat transfer and separation of thin water films under developed boiling.

NOTATION

α, α_l	are the heat-transfer coefficients in a thin film and in a liquid volume;
δ_{film}	is the liquid-film thickness;
q	is the heat-flux density;
λ	is the thermal conductivity of the liquid.

LITERATURE CITED

1. V. I. Tolubinskii, V. A. Antonenko, and Yu. N. Ostrovskii, Inzh.-Fiz. Zh., 32, No. 1 (1977).