transfer coefficient is shown as a function of the product $(W - W_g)d$. Thus, we arrive at a relation of type (1) with the coefficient $A = 3$.

From our analysis of the experimental data we conclude that there is a substantial increase in the mass transfer coefficient under the conditions described (in our experiments up to a factor of 3 at velocities not exceeding 1.5 m/sec).

NOTATION

k is the mass transfer coefficient under nonstationary flow conditions; k_0 is the mass transfer coefficient for motion of the suspension in a tube of constant cross section; A is an empirical coefficient; ΔG is the particle weight loss (determined by weighing before and after dissolution); F is the surface area of the particle; t is the residence time in contact with the liquid; c_s is the saturation concentration of potassium nitrate; W is the fluid velocity; W_g is the particle suspension velocity.

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L'vov Polytechnic Institute

EFFECT OF NEIGHBORING BOILING SECTIONS ON THE CRITICAL HEAT FLUX IN FORCED CHANNEL FLOW

A. A. Ivashkevich

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It is assumed that the critical heat flux is affected by nucleate boiling in neighboring channel sections upstream from the burnout point.

In performing critical heat flux experiments it is usual to measure or calculate the flow parameters (velocity, temperature, vapor content) averaged over the channel cross section. In the general case the distribution of velocity, temperature, and vapor content over the channel cross section is not known. It is natural to assume that burnout depends not only on the averaged values of the flow parameters but also on their distribution over the channel cross section which, in turn, depends on the intensity of the nucleate boiling process in neighboring parts of the channel upstream from the burnout point. The effect of nucleate boiling on burnout diminishes with distance. Therefore it is possible to speak of an effective length on which nucleate boiling affects the critical heat flux:

$$q_{\mathrm{cr}} = f_1(w\rho,\ X_{\mathrm{b}},\ D,\ L,\ \overline{q}_L,\ \overline{X}_L,\ \ldots). \tag{1}$$

In this equation the effect of nucleate boiling in neighboring cross sections is taken into account by the mean heat flux, the mean relative enthalpy of the flow of liquid or vapor-liquid mixture in neighboring cross sections of the channel, and the length of the neighboring boiling sections. Equation (1) does not contain all the parameters affecting burnout: in particular, it does not contain the physical properties of the liquid and the vapor, since since their effect is not considered. Equation (1) has been written for the boiling of both a subcooled liquid ($X < 0$) and a vapor-liquid mixture ($X > 0$).

We will not consider in detail the reason why nucleate boiling in neighboring parts of the channel affects burnout. An explanation has been offered in [1] and the matter is also examined in [2].

The enthalpy of the liquid flow in neighboring cross sections of the channel is linked by the heat balance equation with the enthalpy of the flow in the section in which burnout occurs. If it is less than the heated length of the channel, the length of the neighboring boiling sections depends on the liquid flow parameters in neighboring cross sections of the channel. Thus Eq. (1) may be rewritten as

$$q_{\mathrm{cr}} = f_2[w\rho,\ X_{\mathrm{b}},\ \Gamma_{\mathrm{b}},\ D,\ l_0,\ q_L(l),\ \ldots]. \tag{2}$$

The effect of nucleate boiling in neighboring cross sections of the channel on the critical heat flux in Eq. (2) is taken into account by the liquid enthalpy gradient, the law of variation of the heat flux in neighboring parts of the channel, and the heated length of the channel if it is equal to the length of the neighboring boiling sections of the channel. Although Eq. (2) does not contain all the parameters affecting burnout, it is important to note that it does include a new parameter—the gradient of the liquid enthalpy along the length of the channel. The enthalpy gradient itself does not directly affect burnout; its effect is manifested through the effect of nucleate boiling in neighboring parts of the channel, this effect always existing whenever there are neighboring boiling sections.

In a number of cases the liquid enthalpy gradient is an independent parameter, for example, in annular channels with independent two-sided heating. However, in certain cases it is a dependent parameter, for example, in uniformly heated tubes.

We will consider whether the existing experimental data on critical heat fluxes confirm that nucleate boiling in neighboring sections of the channel affects nucleate boiling burnout. In the light of what has been said [Eq. (2)], as a result of this influence the critical heat flux should depend: 1) on the heat flux distribution along the length of the channel over the neighboring boiling sections; 2) on the liquid enthalpy gradient along the length of the channel, which, in turn, depends on the heat flux distribution over the perimeter of the channel and on the ratio of the heated perimeter to the cross-sectional area of the channel; 3) on the heated length of the channel if it is equal to the length of the neighboring boiling sections of the channel. In fact, in various experiments on the boiling of subcooled liquids and vapor-liquid mixtures the following factors have been found to affect the critical heat flux: 1) the heat flux distribution along the length of a tube [3, 4]; 2) the heat flux distribution over the perimeter of a tube [5] and over the perimeter of an annular channel (one- and two-sided heating) [2, 6]; 3) the ratio of the heated perimeter to the cross-sectional area of the channel (circular tubes, annular channels with inside, outside and two-sided heating, bundles of rods) [6]; 4) the heated length of the tube [7]. On the basis of these experiments it is also possible to estimate the order of the length of the neighboring boiling sections. For a boiling subcooled liquid it is hundredths, and for a boiling vapor-liquid mixture tenths of a meter.

The effect of the flow prehistory on burnout can be checked by interfering with the flow in neighboring cross sections, e. g., by introducing various kinds of turbulence generators, mixers, etc., to equalize the vapor content over the channel cross section. Thus, in [2] it was found that a centering device in an annular channel caused an increase in the critical heat flux.

Thus, in using the flow parameters of the liquid or vapor-liquid mixture averaged over the cross section in which burnout occurs it is necessary to consider the effect of nucleate boiling in neighboring sections of the channel on nucleate boiling burnout. The length of the neighboring boiling sections may be less than or equal to the heated length of the channel. The effect of the neighboring boiling sections on burnout must be taken into account in performing experiments on the critical heat flux and in analyzing, interpreting, and generalizing the results. The same effect should also be taken into account in simulating apparatus cooled by a boiling liquid. The test data obtained on models can be transferred to the actual apparatus: 1) if the characteristic parameters are equal in the channel cross section considered, 2) if there is the same law of distribution of the heat flux along the length and perimeter of the channel over the length of the neighboring boiling sections; 3) if the lengths of the neighboring boiling sections are equal. The heated length of the channel and the variation of the heat flux outside the neighboring boiling sections may be different. We still do not have an expression for the length of the neighboring boiling sections.

NOTATION

q_{cr} is the critical heat flux; $w\rho$ is the mass flow velocity of liquid or vapor-liquid mixture; $X = (i' - i)/r$ is the relative enthalpy of flow; i' is the enthalpy of liquid at saturation point; i is the enthalpy of flow of liquid or vapor-liquid mixture; r is the heat of vaporization; D is the transverse dimension of channel; L is the length of neighboring boiling sections; $\Gamma = di/dl$ is the liquid enthalpy gradient along the length of the channel; l_0 is the heated length of the channel; $q(l)$ is the law of heat flux variation. Subscripts: b is the value in the channel cross section in which burnout occurs; L is the value over the length of the neighboring boiling sections.

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Institute of Physics and Power Engineering, Obninsk

ENGINEERING FORMULAS FOR CALCULATING THE FRICTION ON A PERMEABLE SURFACE IN A TURBULENT GAS FLOW

V. D. Sovershennyi

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Simple formulas are proposed for calculating the friction on a permeable surface in a turbulent gas flow.

In several theoretical studies of a turbulent boundary layer with blowing, satisfactory agreement has been obtained between the calculated and experimental values. However, in most cases, theoretical calculations are laborious and inconvenient for engineering purposes. This note presents simple formulas for calculating the coefficient of friction on a permeable plate in a turbulent gas flow.

The proposed formulas were obtained on the basis of an approximation of the curves calculated from the theoretical formulas of [1].

We write the coefficient of friction as a function of the blowing parameter in the exponential form

$$c_f/c_{f_0} = \exp\,(-k\,\alpha). \tag{1}$$

This is convenient, since from the results of [1] it has been established that the coefficient k is almost independent of the blowing parameter α. The coefficient k depends on other parameters, for example, the molecular weights of the main-stream and blown gases. An analytic expression giving k as a function of the parameters of the problem can be established by approximating the theoretical relations obtained in [1].

In the particular case of a subsonic isothermal flow we obtain the following approximation for the coefficient k:

$$k = \frac{1}{2}\left(\frac{m_2}{m_1}\right)^{0.6}. \tag{2}$$

Similarly, we can establish the relation between k and the other parameters; however, it should be noted that k depends most strongly on the ratio of molecular weights.

From (1) and (2) we obtain a formula for calculating the friction on a permeable surface in a subsonic isothermal gas flow in the form

$$\frac{c_f}{c_{f_0}} = \exp\left[-\frac{\alpha}{2}\left(\frac{m_2}{m_1}\right)^{0.6}\right]. \tag{3}$$