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THE RELATION BETWEEN HEAT FLUX AND ACOUSTIC PRESSURE IN LIQUID BOILING

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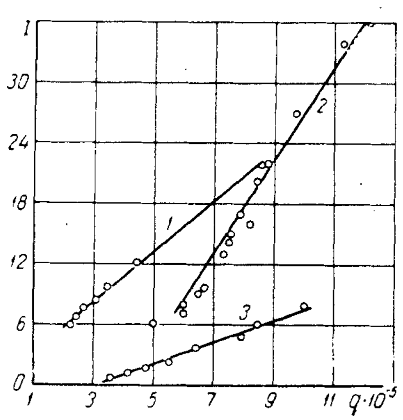
An investigation has been made of the dependence of noise intensity on superheat in local boiling of distilled degassed water and ethyl alcohol. The figure shows graphs of acoustic pressure I as a function of heat flux q for temperature differences $\Delta T = T_2 - T_1$ at various liquid temperatures. It can be seen from the graphs that at a given temperature of the medium T_0 there is a straight line relation between heat flux and noise intensity.



Dependence of acoustic pressure in boiling liquids on heat transfer: 1,2) Water at T_0 = 365° K and 338° K; 3) alcohol at T_0 = 307° K.

Since the heat flux in nucleate boiling is determined by the number of vaporization nuclei [1], it may be assumed that the noise intensity of a boiling liquid in the case T_0 = const also depends on the number of such nuclei. This conclusion agrees with Nesis' hypothesis [2], according to which the sound in boiling is associated with volume fluctuations of the vapor bubbles. The number of bubles emitting sound increases with the number of vaporization nuclei.

A platinum wire of diameter 0.19 mm and length 25 mm was used as the heating surface. The acoustic pressure in boiling was determined by an acoustic detector. The detector voltage was fed to a vacuum-tube voltmeter amplifier and then to a square-law voltmeter.

The wire temperature was measured using a bridge circuit, with a galvanometer of sensitivity 10^{-9} a/div as measuring instrument. The bridge and the heater were simultaneously supplied from a stabilized rectifier. The heat flux was determined using an ammeter and a class 0.5 voltmeter.

NOTATION

T_2 — wire temperature; T_1 — boiling point; T_0 — temperature of surrounding liquid; I — acoustic pressure in millivolts; q — specific heat flux.

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A TWO-DIMENSIONAL PROBLEM OF STEADY HEAT CONDUCTION

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Approximate solutions have been obtained [1, 2] and [3] for the problem of steady heat conduction in a semi-infinite block with internal cylindrical heat sources (distributed channels of circular cross section). The authors, however, do not comment on the degree of approximation of the solutions.

The solution [1, 3] for the case when the block is cooled by a system of recessed channels ($t_s > t_0$) has the form

$$\bar{t} = \frac{t - t_0}{tg - t_0} = 1 - \frac{1}{2\bar{R}} \ln \frac{\operatorname{ch}(2\pi/S)(y + h_0) - \cos(2\pi/S)x}{\operatorname{ch}(2\pi/S)(y - h_0) - \cos(2\pi/S)x}, \tag{1}$$

where

$$\bar{R} = 2\pi\lambda(tg - t_0)/q.$$

To satisfy the boundary condition $\bar{t} = 0$ ($t = t_0$) over all the initial circular contour, we have only two constants in Eq. (1) – h_0 and $\bar{R}$. With their aid this condition can be satisfied only at two arbitrary points on the contour. Therefore Eq. (1) solves the given problem to a certain approximation.

Substituting into (1) the coordinates of points $A_1(0, h - r)$ and $A_2(0, h + r)$ located on the vertical diameter of the initial circular contour, we obtain a system of two equations in two unknowns h_0 and $\bar{R}$; solving this, we have

$$\operatorname{ch} \frac{2\pi}{S} h_0 = \operatorname{ch} \frac{2\pi}{S} h \operatorname{ch}^{-1} \frac{2\pi}{S} r, \tag{2}$$

$$\operatorname{ch} \bar{R} = \operatorname{sh} \frac{2\pi}{S} h \operatorname{sh}^{-1} \frac{2\pi}{S} r. \tag{3}$$

As far is known, expressions in this form, which is most convenient for practical calculation, were not obtained either in [1, 2] or in [3].

Substituting (2) and (3) in (1) and making some transformations, we obtain the equation of the isotherm $\bar{t} = 0$ in explicit form:

$$\cos \frac{2\pi}{S} x = \operatorname{ch} \frac{2\pi}{S} (y - h) \operatorname{ch}^{-1} \frac{2\pi}{S} r, \tag{4}$$

where $-r < x < r, \quad h - r \leqslant y \leqslant h + r.$

Equation (4) describes an elliptic-type curve symmetrical with respect to the y axis and the line $y = h$, where r is the semimajor and r_1 the semiminor axis (value of x at $y = h$).

Analysis shows that when $r/S > 0.1$, the value of r_1 begins to fall sharply compared to that of r; for the limiting value $r = 0.5S$, $r_1 = 0.237S$. When $r/S \leq 0.1$, $0.945r \leq r_1 < r$, and the contour of the isotherm $\bar{t} = 0$ practically merges with the given circular contour; consequently, Eq. (1) gives a sufficiently accurate solution of the problem only within these limits.

NOTATION

t_g – surface temperature of block; t_0 – temperature of channel surface; $\bar{t}$ – relative excess temperature at point considered; q – heat flux per unit length of channel; λ – thermal conductivity of block; S – channel spacing; h – ordinate of channel axes; r – channel radius; h_0 – ordinate of point heat sink; $\bar{R}$ – dimensionless thermal resistance of unit length of channel.

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