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LETTER TO THE EDITORS

ON THE EFFECT OF MOLECULAR-KINETIC RESISTANCE UPON HEAT TRANSFER WITH CONDENSATION

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IN THE paper by Madejski [1], published in this Journal, an inaccurate assumption was made by the author in formula (1.9) when deriving the dependence of quantity β as inverse to the thermal resistance at the phase interface. As a result, the conclusion of the author of that paper about the great effect of the resistance at the interface, even in the case when the condensation (accommodation) coefficient $a = 1$, is at variance with the data obtained in other investigations.

Proceeding from the same equations of the kinetic theory, which were used by the author of the paper considered, it is possible to obtain [2]:

$$\beta = \frac{a\Delta h}{(T'' - T')\sqrt{(2\pi R/M)}}\left(\frac{P''}{\sqrt{(T'')}} - \frac{P'}{\sqrt{(T'')}}\right) \text{W/m}^2\text{s.} \quad (1)$$

The notation used in this equation and below is the same as in paper [1].

In the limiting case, when the heat flux $q \to 0$ it is possible, using the Clapeyron–Clausius equation, to reduce formula (1) to the following form obtained in paper [3]:

$$\beta = \frac{a(\Delta h)^2 P'' M}{R(T'')^2\sqrt{(2\pi R T''/M)}}. \quad (2)$$

The author of paper [1] has assumed that $P' = P'' = P$ and has obtained (see formula (1.9) of paper [1]):

$$\beta = \tfrac{1}{2} a\rho''\,\Delta h \sqrt{\left(\frac{R}{2\pi M T''}\right)} = \frac{a\,\Delta h P''}{2T''\sqrt{(2\pi R T''/M)}}. \quad (3)$$

For the numerical example given in paper [1] ($d = 4$ mm, $P'' = 0{\cdot}0513\,.\,10^5$ N/m², $\Delta T = 2$ degC and $a = 1$), the calculation using formulae (1) and (2) gives $\beta \approx 730\,000$ W/m²s, hence $\alpha_m/\alpha_{m\,.\,N} \approx 1$, whereas according to formula (3) we have $\beta = 21\,100$ W/m²s, hence $\alpha_m/\alpha_{m\,.\,N} = 0{\cdot}54$. These equations show that the assumption $P' = P''$, made when deriving formula (3) and which is not valid for the case under consideration, has led to the underestimation of the quantity β by a factor of approximately thirty-five and to that of the heat-transfer coefficient α_m by almost two.

Generally speaking the upper limit of the value of the condensation coefficient a is greater than unity. It may be written that $a = k\,.\,a_*$ where k is the correction factor taking into account the effect of the deviation of a real velocity distribution of vapour molecules with condensation, from the Maxwell one for an ideal gas at rest, and a_* is the condensation coefficient in the Hertz–Knudsen formula. According to the data of paper [4] if we do not take into consideration the distinction between the properties of the vapour and ideal gas, which is permissible at low pressures, we have $k = 2/(2 - a_*)$, hence at $a_* = 1$ we obtain $a = 2$. Moreover, for this value of "a" when formulae (1) and (2) are used it is possible to obtain that $\beta \approx 1\,460\,000$ W/m²s. An even smaller effect of the resistance at the interface upon the heat-transfer coefficient corresponds to this fact. The data on the values of the condensation coefficient for a number of liquids, including water, are still contradictory. For water these values reach 0·001–0·05. I should like to note here that no large effects of resistance at the interface were revealed in the experiments on water vapour condensation even at relatively low densities of order (0·03–0·05) × 10^5N/m². This experimental data supports the view that the condensation coefficient for water is close to unity.

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