curve of the heat-transfer agent, where the pressure difference required to force the heat transfer agent into the evaporation zone is provided by a smaller temperature difference. the pressure difference required to force the heat transfer agent into the evaporation zone is provided by a smaller temperature difference.

In Fig. 4b we have plotted the surface heat flux density in the evaporation zone (at the temperatures indicated in Fig. 2b) against the difference of the evaporator wall and saturated vapor temperatures.

NOTATION

Q, heat flux in pipe; q, heat flux density; ρ, density; m, mass; r, heat of vaporization; ϕ, angle of inclination of pipe with respect to horizontal; g, acceleration of gravity; h, distance between beginning of vapor channels in evaporator lining and uncompensated level of liquid in heat pipe; d_p, wick pore, diameter; Π, wick porosity; l_1, l_2, l_3, l_4, l_5, l_6, and l_7, lengths of heat pipe, evaporating chamber, heat exchanger (condenser), wick, vapor channels, injector mixing chamber, and distance between nozzle and mixing chamber, respectively; D_1, D_2, D_3, D_4, D_5, and D_6, inside diameters of evaporating chamber, evaporator reservoir, nozzle, mixing chamber, vapor channels, and circulation loop tubes, respectively; δ_1, distance of vapor channel from evaporating chamber wall; δ_2, distance between vapor channels; T_w^{ev}, evaporator wall temperature; T_w^c, condenser wall temperature; T_{cw}, temperature of cooling water; u, circulation and evaporator feed flow ratio.

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EXPERIMENTAL STUDY OF LOCAL HEAT EXCHANGE BETWEEN AN INCLINED PLATE AND AN IMMOBILE

N. Ya. Romanenko and D. A. Kazenin UDC 66.015.24:536.24

The local heat-liberation-coefficient distribution is described for the surface of a plate immersed in a dispersed layer, with the angle of incidence to the main gas flow varied over a wide range.

The recent wide use of boiling layers as heat-transfer media in the operation of immersed heat exchanges requires more detailed study of the intensity of heat liberation from bodies located in dispersed layers.

The literature has considered the questions of local heat exchange from vertical and horizontal tubes and tube clusters immersed in a layer, and from vertical and horizontal plates [1-3]. The effect of the orientation of the immersed body relative to the incident flow of draft medium has been considered in less detail [4-7]. The latter studies considered the cases of flow around a plate inclined at 45° to the vertical, with 40-50% of the cross section obstructed.

The goal of the present study is a clarification of the distribution of the heat-liberation coefficient over the surface of a small plate immersed in a dispersed layer over a wide range of attack angle in both an immobile and a boiling layer.

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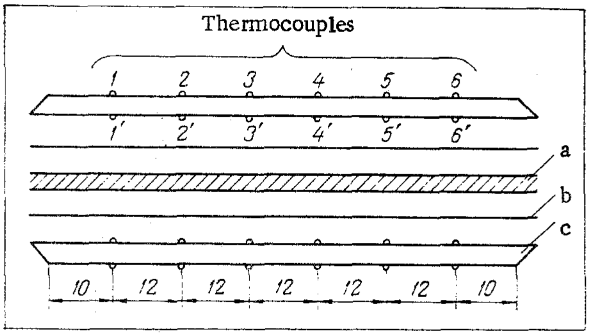

Fig. 1

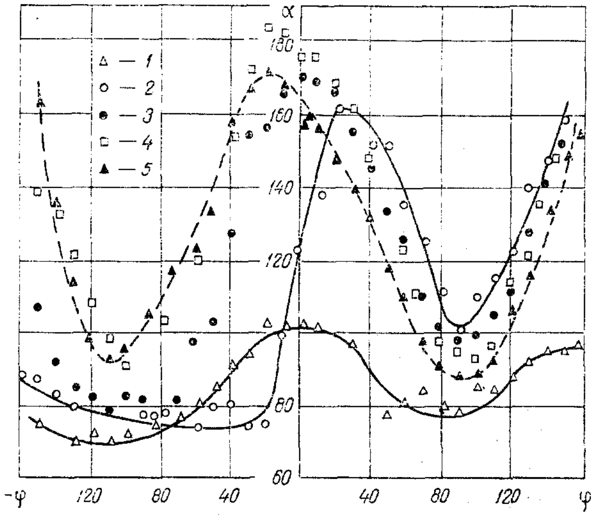

Fig. 2

Fig. 1. Method of thermocouple attachment to plate (a) heater; b) mica insulator; c) beechwood plate.

Fig. 2. Heat-liberation coefficient averaged over one surface versus angle of plate rotation and gas flow rate: 1) W = 0.8; 2) 1.3; 3) 2.0; 4) 2.5; 5) 3.0.

Statement of the Problem.

In measuring time averages of local coefficient values it is desirable to create one-dimensional propagation of thermal fluxes — along the normal to the plate surface. Moreover, for more accurate measurement of local thermal flux values q, large temperature drops are required between the heater and the outer surface of the plate. These requirements were satisfied with a specially designed experimental plate. The plate was constructed of beechwood because of its quite low (0.2-0.4 W/m•°C) thermal conductivity and was cut across the wood grain to utilize the anisotropy of the wood's thermal conductivity. The conductivity of beechwood along the grain is twice as high as across the grain. With this construction temperature drops from 20 to 70°C along the grain were achieved (for a plate thickness on the order of 4 mm). At the same time, thermal fluxes along the surface were approximately 80 times smaller than along the normal to the surface, which permits us to consider the heat flow as one-dimensional.

The dimensions of the plate were as follows: height, 80 mm; width, 90 mm; assembled thickness, 8.5 mm. A diagram of the construction is shown in Fig. 1.

The plate construction permitted changing its angle of inclination to the vertical from +160° to —160°.

The plate axis was attached at a distance of 120 mm from the grid; with the plate vertical the lower edge was 80 mm from the grid.

Measurements were performed in an apparatus 172 mm in diameter with a grid made of layers of felt, porolon, and a metal screen with 10-μ cells. Covering height was 200 mm. The dispersed material used was a narrow fraction of spherical aluminosilicate catalyst d = 2.5-3.0 mm (residue between 2.5- and 3.0- mm sieves with circular orifices) with a critical liquefaction velocity of 0.85 m/sec. Air supply rate was varied from $8 \cdot 10^{-3}$ to 3 m/sec.

Thermal load was varied from 1.0 to 3•5 kW/m² with the limitation that the external wall temperature not exceed 120°C.

In preceding studies [8, 9] local heat-liberation coefficients as functions of height of a vertically oriented plate have already been presented, and a semiempirical method was proposed for calculation of α-fields of such plates.

Experimental Results

Figure 2 presents values of heat-liberation coefficients averaged over one plate surface as a function of the pseudoliquefaction number and angle of rotation.

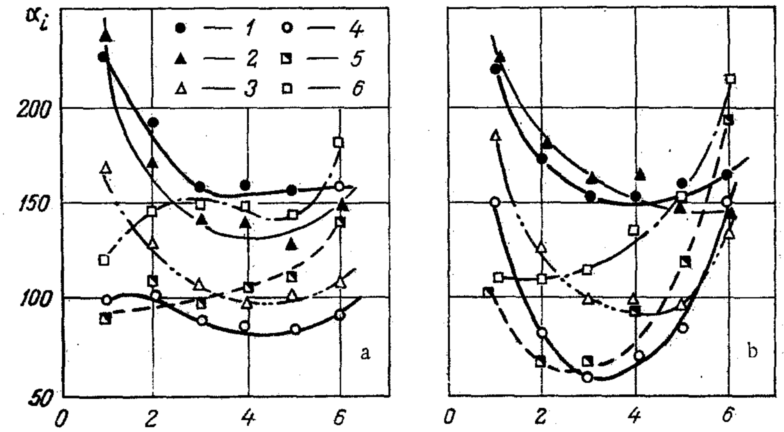

Fig. 3. Local heat-liberation-coefficient distribution over plate height versus angle of rotation at flow rate 2.5W: a) front surface; b) rear surface; 1) +0°; 2) +30; 3) +60; 4) +90; 5) +120; 6) +150°. α_i, W/m²·°C.

The positive angles here correspond to a position such that the plate surface over which α is averaged is directed toward the incident flow (front surface), while for negative angles this surface is directed upward (rear surface).

We note the interesting tendency to change in $\bar{\alpha}$ with velocity for negative angles (rear plate surface).

At low gas velocities (W = 0.8 and 1.2) $\bar{\alpha}$ depends weakly on the angle of rotation, but with increase in velocity $\bar{\alpha}$ increases by a factor of two or more and at pseudoliquefaction numbers of 2.5-3.0 an almost symmetric picture is obtained for positive and negative angles of inclination.

With variation of angle the position of the maximum $\bar{\alpha}$ value shifts from +20 at velocities close to commencement of liquefaction to —20 for developed liquifaction (W = 2.5-3.0).

It is obvious that at low gas velocities a cap of particles is formed on the rear surface of the plate, which moves only slightly relative to the screening body. With increase in gas flow, particle motion becomes more intense which leads to equalization of $\bar{\alpha}$ values on the front and back surfaces.

It is interesting that the heat-liberation coefficients in the positive angle of incidence range are already quite large at low liquefaction numbers (1.3W). Moreover, in this range of angles, where the surface is turned toward the incident flow, the mean α values decrease with increase in gas velocity. The maximum in $\bar{\alpha}$ as a function of velocity usual for pseudoliquefaction, which is observed at liquefaction numbers on the order of 2.5, is also characteristic of the present experiment, but only for the attack angle range of ±30°. Then with a greater positive angle $\bar{\alpha}$ drops with increase in velocity. In our opinion, this is related to the fact that the plate strongly obstructs the cross section of the apparatus. For change in angle from 0 to 90° the fraction of the area obstructed changes from 3 to 30%. Most probably the picture in the positive angle range corresponds to the descending branch of the α(W) curve. When the averaging surface is directed upward the situation changes. Here in the negative angle range due to the increase in particle circulation along the surface with increase in W, the mean heat-liberation coefficients increase.

At a flow rate of 1 cm/sec (filtration) the heat-liberation coefficients averaged over both sides of the plate are practically independent of the angle of plate rotation and vary over the range 10-12 W/m²·°C.

With a plate position close to vertical, for local α_i values as a function of height it is characteristic (Fig. 3) that there is a sharp drop from the lower edge to the middle of the plate with a subsequent slight change. With increase in inclination the nonuniformities on the front side smooth out, while those on the rear increase. With a horizontal plate position (90°) the α_i values on the surface directed toward the flow are practically constant. On the opposite side at the plate edges they are 3-4 times as high as in the core of the flow and the heat-liberation coefficients are practically the same as in the case of an immobile drafted layer.

TABLE 1

Thermocouple number	1	2	3	4	5	6
Distance from lower edge of plate (mm)	10	22	34	46	58	70
Attack angle at which min α_i is observed	—140°	—120°	—100°	—80°	—60°	—40°

It is appropriate to compare the hydrodynamics of gas flow in the slightly mobile particle cap on the rear surface of the plate with potential flow around a plate in a Darcy filtration. The latter, as is well known, is determined within the accuracy of an arbitrary circulation whose value determines the location of the rear critical point. Thus, according to the hypothesis of circulationless flow the rear critical point shifts from the center of the plate to the rear edge by a cosine law. At the same time, according to the hypothesis of smooth stream convergence (Chaplygin—Zhukevskii postulate) the rear critical point is always located at the rear edge. The heat-liberation distribution for the rear side presented in Fig. 3b allows a conclusion as to the truth of the hypotheses. Thus, the presence of a clearly expressed minimum in the heat-liberation distribution favors the first hypothesis. This is especially clear from Table 1 presented below, where the shift in the heat-liberation minimum, while always located on the back surface, correlates well with the motion of the rear critical point for circulationless flow. This confirms our direct pneumometric measurements with a dynamic pressure head tube located vertically at various points above the plate. These data also show a minimum in the region of the proposed position of the rear critical point. At the same time, at small plate inclinations (up to 30°) neither pneumometric or thermal data show a clear minimum on the rear surface, so that the hypothesis of critical point location on the rear edge is more probable (Table 1).

It should be noted that the position of α_i is practically independent of gas velocity (observed with liquefaction numbers from 0.8 to 3.0).

Maximum values of local heat-liberation coefficients were observed as a function of velocity in the angle range ±30°. No clear-cut dependence of max α_i on velocity could be observed.

The experimentally measured values of local heat-liberation coefficients for a gas belocity of 1 cm/sec will not be presented, but it may be said that α_i in this case is an order of magnitude smaller than in the pseudoliquefied layer, although the character of the dependence of α_i on angle of incidence is very similar to the picture for pseudoliquefaction.

NOTATION

q, local heat flux, W/m²; α_i, time-averaged local heat-liberation coefficient, W/m²·°C; $\bar{\alpha}$, heat-liberation coefficient averaged over one surface, W/m²·°C; W, liquefaction number.

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