EFFECT OF HEAT LOAD ON HEAT TRANSFER IN A FOAM LAYER

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Results are presented of an experimental investigation of heat transfer from heated surfaces surrounded by a gas-liquid foam layer in the case of large specific heat fluxes. The temperature of the heat-transfer surface in a foam layer is much lower than in the case of boiling with approximately the same specific heat flux.

The experiments were carried out at atmospheric pressure in a column of cross section 120 × 120 mm with a water-air system at gas velocities W = 0.4–4.5 m/sec in the free section of the apparatus.

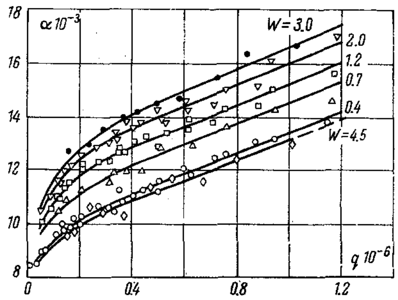

Fig. 1

The air was delivered through a screen with parameters d_0 = 3 mm, m = 8 mm, S_0 = 0.08 at W = 0.4–2.0 m/sec and d_0 = 3 mm, m = 5 mm, S_0 = 0.192 at W = 3.0–4.5 m/sec.

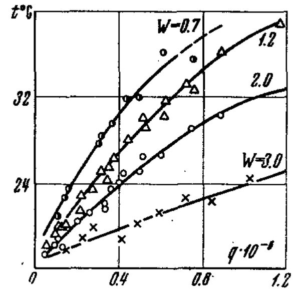

Fig. 2

The heat transfer elements were copper tubes 0.2 mm thick and 4 mm in diameter mounted at a distance of 75 mm from the screen. These tubes were heated by low-voltage ac current from a MSR-25 contact welding transformer, which could provide specific heat fluxes up to $1.2 \cdot 10^6$ W/m^2.

The foam temperature was measured with six copper-constantan thermocouples. The wall temperature was measured in two ways: by nine thermocouples welded to the outer surface of the tube, and by one movable thermocouple on the tube axis [1, 2]. The ends of the tubes were sealed with plugs to prevent movement of the air inside the tubes.

The experiments at W = 0.4–2.0 m/sec carried out with a constant foam height of 160 mm. At W = 3.0 and 4.5 m/sec, when the foam layer lacked a distinct upper boundary, we also measured the initial water levels on the screen, which were 36 and 14 mm, respectively.

Figure 1 shows the heat transfer coefficient α in W/m^2 · deg as a function of the heat flux density in W/m^2 for different W. Figure 1 shows that α increased with increase in q and W up to ~ 3 m/sec. With further increase in gas velocity the values of α began to decrease. This can be attributed to the reduction of heat transfer due to the transition from foam to spray.

It should be noted that the temperature of the heat-transfer surface with $q = 10^6$ W/m^2 was approximately 85° C at $W = 3$ m/sec and 100° C at $W = 1.2$ m/sec. In the case of pool boiling of water at atmospheric pressure a wall temperature of about 130° C corresponds to the critical heat flux ($q_* \approx 10^6$ W/m^2).

Thus, the conditions for heat transfer in foam are better than the conditions associated with boiling. In addition, it should be noted that the specific heat fluxes obtained in the experiments were not the maximum values for foam and were limited by the performance of the transformer.

The foam temperature t in the experiments did not exceed 38° C (Fig. 2). The figure shows that, as was to be expected, the foam temperature increased more rapidly with increase in q in the case of low gas velocities in the column.

Figure 3 shows q as a function of the difference in temperatures of the wall and foam for W = const.

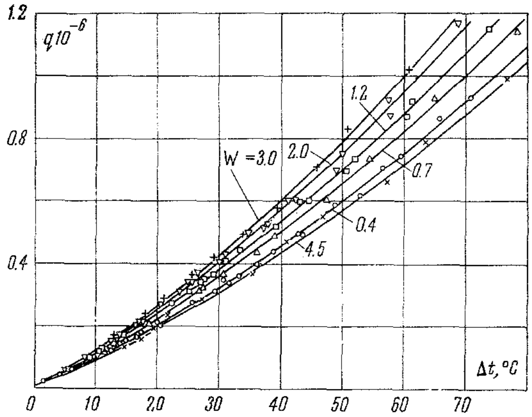

Fig. 3

The obtention of the relationship $\alpha = f(q, W)$ in the form of a power function

$$\alpha = Cq^m W^n \tag{1}$$

is of definite practical interest.

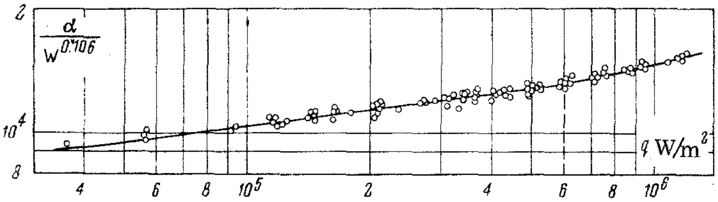

Fig. 4

In the considered velocity range W = 0.4–3 m/sec we obtained n = 0.106 from an analysis of the experimental data.

Figure 4 shows the experimental data for the heat transfer from the wall of the heat-transfer element to the water-air foam in the form of the relationship $\alpha/W^{0.106} = f(q)$ in logarithmic coordinates. The index of the power of q (W/m^2), as the figure shows, has different values for two regions of q.

As a result we obtain

$$\alpha = 2190\, q^{0.135}\, W^{0.106} \text{ for } q = 4 \cdot 10^4 \div 6 \cdot 10^5 \text{ W/m}^2 \tag{2}$$

$$\alpha = 612\, q^{0.231}\, W^{0.106} \text{ for } q = 6 \cdot 10^5 - 1.2 \cdot 10^6 \text{ W/m}^2 \tag{3}$$

The differences between the values of the heat transfer coefficients determined from formulas (2) and (3) and the experimentally obtained values did not exceed ±5%.

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