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EFFECT OF BRIEF THERMAL PULSES ON INTENSITY OF HEAT LIBERATION IN HELIUM BOILING

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UDC 536.248.2:546.291

Results are offered from a study of heat liberation in boiling of liquid helium upon a heated wall under impulsive thermal action conditions.

Bubble boiling of helium is characterized by significant ambiguity in the amount of superheating of the heat liberating wall, given one and the same heat load on the heat exchange surface. Thus, it was shown in [1-4] that for slow (quasisteady-state) increase in thermal flux density the wall superheatings recorded at specified q values may be several times higher than upon subsequent reduction in thermal load. This is caused by the fact [4] that in the course of q reduction a significant fraction of the previously (upon increase in q) activated vapor formation centers continue to act, providing a high heat exchange intensity.

In [5-7] a reduction in superheating of heat liberating wall was observed in helium boiling for the case of action upon the wall by a brief light pulse. The authors of those studies assume that upon absorption of the light pulse energy the heat liberating surface emits photoelectrons, which act as vapor bubble formation centers. An increase in the number of boiling centers leads to intensification of heat exchange and reduction in wall superheating.

The present study examined the effect of short thermal pulses on heat liberation into helium boiling under large volume conditions at atmospheric pressure. The experiments were performed with the working chamber described in [8]. The heated wall consisted of a ribbon of brass foil 65 × 4 × 0.05 mm in size, thermally isolated on one side. The foil was heated by direct passage of electric current.

The operating section R_W (see Fig. 1) was connected in series with reference resistor R_r to the input of power amplifier PA. The current flowing in the circuit was set by current regulator CR. The temperature of the heat liberating surface was determined by a low-inertia germanium film resistance thermometer T. The voltage drop across the thermometer was applied to the special amplifier A, the signal from which was recorded by loop oscilloscope LO. A simultaneous recording was made of the current being fed to the working section heater. Current pulses were created by current generator G, a type G5-54. Current change over the period

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Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 53, No. 3, pp. 373-376, September, 1987. Original article submitted July 4, 1986.

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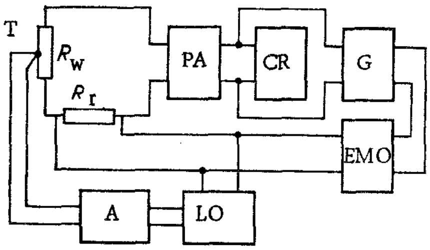

Fig. 1. Electric circuit of operating section.

of the pulse was determined from oscillograms recorded on the screen of an S8-13 electronic memory oscilloscope EMO.

Figure 2 shows the relationship between thermal flux density and the temperature head obtained upon slow change in heater power. Hysteresis can clearly be seen in the helium bubble-boiling curve, analogous to that observed previously in [1-4]. In the case under consideration boiling commences on the heat liberation surface at $\Delta T \simeq 0.24$ K, which corresponds to an abrupt change in the slope of the experimental curve (point B in Fig. 2). Intensification of heat exchange due to continuous increase in the number of vapor formation centers acting on the heating surface takes place in the narrow temperature head range of 0.24-0.30°K, after which a new change in slope of the boiling curve (point C) occurs in the critical thermal load region. With decrease in thermal flux from this load region the high level of heat liberation is maintained even at wall superheatings of ~0.05 K.

Results of one of the experiments in which the effect of heat liberation by short thermal pulses was studied are shown in Fig. 3. Initially the heater current was increased slowly, which led to a gradual increase in temperature of the heat liberating wall. After stabilization of the regime at some constant thermal load value a brief electrical pulse was sent through the heater. The moment of pulse passage corresponds to a peak in the current curve recorded on the loop oscilloscope tape. At the same time, no peak was found in the oscillogram of superheating of the heat liberating wall. This can be explained by the brevity of the additional thermal action ($\sim 2 \cdot 10^{-4}$ sec) and the significant ($\sim 5 \cdot 10^{-4}$ sec) inertia of the temperature measurement circuit. After passage of the pulse superheating of the heated wall falls off sharply.

In all of our experiments the thermal load at which the short electrical pulse was applied to the heater was constant and equal to 145 $\mathrm{W/m^2}$. This load corresponded to weakly developed bubble boiling of the helium on the heating surface at increasing q (point E in Fig. 2). From experiment to experiment the amplitude of pulsed current was varied while the pulse duration was maintained practically constant. The maximum thermal flux during pulse action did not exceed $0.3q_{cr}$.

A variable decrease in superheating of the heat liberating surface was observed, depending on the energy liberated in the pulse. The minimum energy (per unit surface) at which a marked reduction in ΔT was recorded was 0.06 $\mathrm{J/m^2}$. For energies of 0.24 $\mathrm{J/m^2}$ and higher wall superheating decreased to one and the same value, ~0.2°K, i.e., to the value of ΔT which corresponds to the high level of heat liberation (point F in Fig. 2) observed upon slow reduction in thermal flux density from the region of critical thermal loads (beginning at point C on the boiling curve).

The results obtained can be explained in the following manner. Increase in heat liberation in the heater during the time of action of the electrical pulse leads to short-term additional superheating of the wall and the adjacent layer of liquid helium. If this superheating is sufficient for activation of new vapor formation centers, the pulse may cause intensification of heat exchange (reduction in ΔT), since some portion of the activated centers are capable of continuing to generate vapor despite the drop in temperature head. It is obvious that pulses of different energies will activate different quantities of vapor formation centers on the heating surface. Under the present experimental conditions an energy of 0.06 $\mathrm{J/m^2}$ liberated during pulse action was apparently too low to create stable vapor bubble formation centers in the boiling helium. On the other hand, a pulse energy of 0.24 $\mathrm{J/m^2}$ was sufficient to activate all centers which appear during slow increase of thermal flux density to the value corresponding to point C of Fig. 2. This led to coincidence of the wall superheating for a given thermal flux in the final stage of the nonsteady state process under impulsive thermal

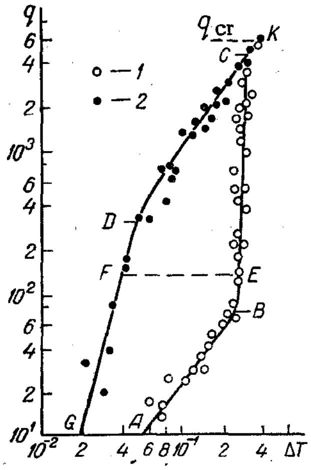

Fig. 2. Heat liberation during helium boiling in large volume: 1, 2) for increase and decrease in thermal load respectively; AB) natural liquid convection without boiling; BC) vapor formation center activation regime; K) boiling crisis; KD) fully developed bubble boiling; DG) termination of vapor formation center action. q, W/m^2; ΔT, °K.

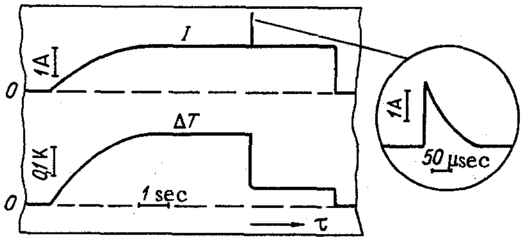

Fig. 3. Oscillogram of transient thermal process.

action with the temperature head at point F on the "descending" branch of the steady state boiling curve.

Thus, the results of the present study indicate a possible method for intensifying heat exchange in boiling helium by applying a brief thermal pulse to the heater. It can also be concluded that even short-term uncontrolled or accidental increase in heater power during experiments with boiling helium can lead to significant scattering of experimental data on heat liberation.

NOTATION

I, current, A; q, thermal flux, W/m^2; q_{cr}, critical thermal flux, W/m^2; ΔT, wall superheating, K; τ, time, sec.

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