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Peculiarities of temperature fields formation in vapor channels of thermosyphons with heat carriers boiling at low temperatures

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Abstract. We conducted experiments on specially developed setup consisting of evaporation, transport and condensation parts. Heat was supplied to the evaporation part by the heating element which was supplied with voltage and alternating current from a single-phase transformer. Temperatures in the characteristic sections of each part were recorded by thermocouples. Junctions of thermocouples were mounted on the axis of symmetry in the liquid layer, at the lower boundary, in the middle part, and at the upper boundary of the vapor channel. To minimize the influence of the random factors (ambient air movement, operation of ventilation system, room temperature, etc.), we placed thermosyphon in a glass box. We used N-pentane as a heat carrier, and the filling ratio of the thermosyphon is equal to 4%.

1 Introduction

Closed two-phase thermosyphons as a device for transferring heat from the high-temperature zone of energy-saturated equipment have been known for a long time [1, 2]. But, despite the fact that in recent years there has been a noticeable increase in numbers of researches devoted to heat transfer processes in thermosyphons [3, 4], there are still few examples of their real usage in modern technologies Among the numerous problems of analyzing the relationships between the characteristics of thermosyphons and their design parameters, the most important tasks are to assess the "performance" of thermosyphon (heat transfer intensity) and analyze the influence of the main significant factors on this target function (using the terms of the experimental design theory). In many cases the main characteristic of thermosyphon operation is its effective thermal conductivity or thermal resistance. But these characteristics usually provide only integral assessment of the thermosyphon performance and are not a basis for analyzing the behavior of heat transfer in such complex heat exchangers.

The information about temperature fields of characteristic parts of thermosyphon is the most significant for physical analysis. However, this kind of measurements presents the objective difficulties. For this reason, the results of temperature measurements are given in many works only on separate parts of the outer surfaces (Ts) of such heat exchanger [7, 8]. As a result of a rather intensive heat transfer across the body of the thermosyphon along the

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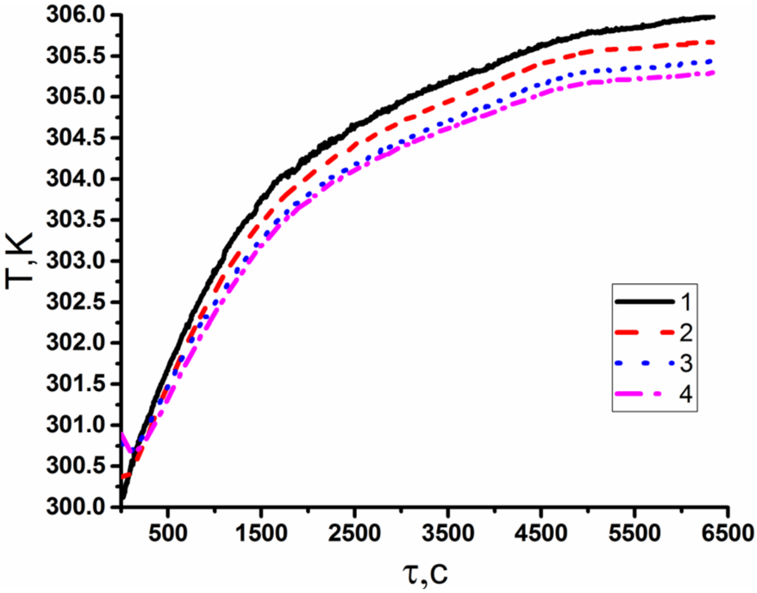
transverse and longitudinal coordinates, Ts measurements are not enough to analyze the processes in the evaporation and condensation parts, as well as in the vapor channel. A few results of temperature measurements inside the thermosyphon [9, 10] reflect their change only at certain points of the internal surface of this device. In order to conduct intrinsic analysis of heat transfer behavior, we need to obtain the information about temperature distributions or at least gradient T at separate parts corresponding to zones of vapor evaporation, transport and its condensation.

The purpose of this work is to determine experimentally temperature fields in the evaporation, transport and condensation parts in a closed two-phase thermosyphon using the example of a low-boiling heat carrier of N-pentane.

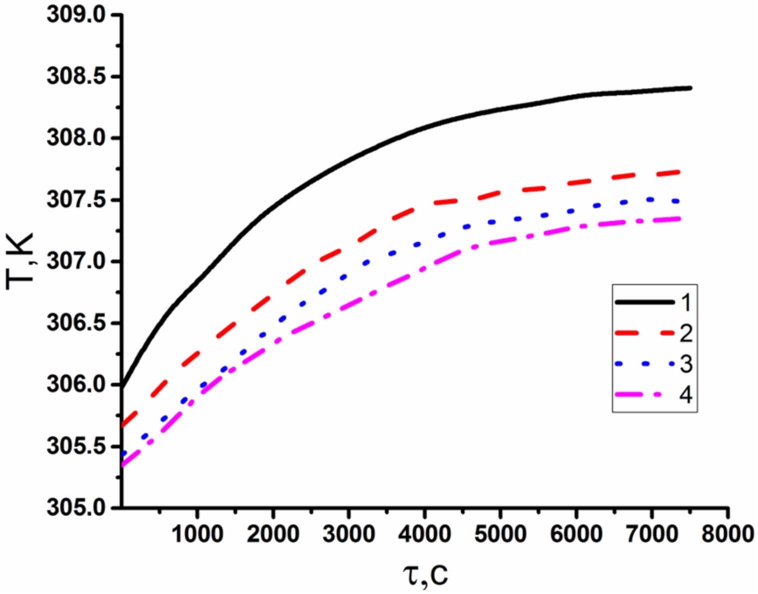
2 Results and discussion

We conducted experiments on specially-developed setup [11], where evaporation, transport and condensation parts were separated. Heat was supplied to the evaporation part by the heating element which was supplied with voltage and alternating current from a single-phase transformer. Temperatures at the characteristic sections were registered by thermocouples. Junctions of thermocouples were mounted on the axis of symmetry in the liquid layer, at the lower boundary, in the middle part, and at the upper boundary of the vapor channel. To minimize the influence of the random factors (ambient air movement, operation of ventilation system, room temperature, etc.), we placed thermosyphon in a glass box. The filling ratio of the thermosyphon with N-pentane was equal to 4%.

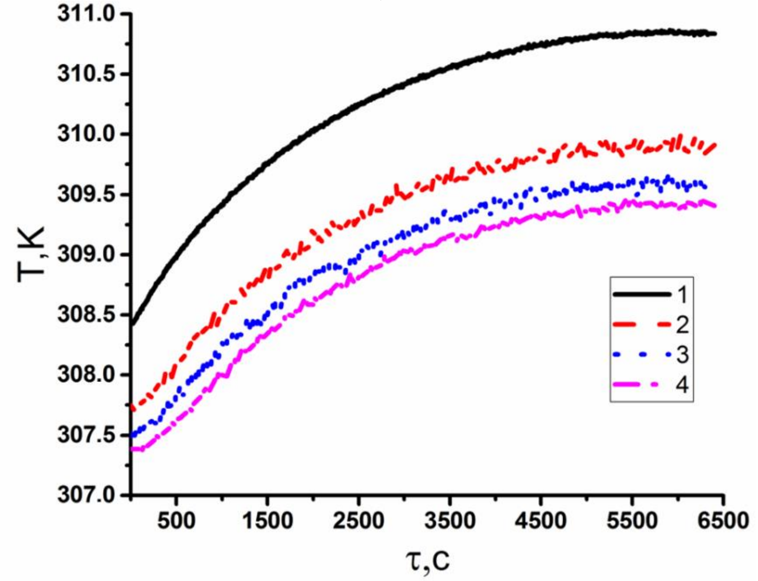
Figure 1 presents typical thermograms of cavity of thermosyphon in the range of heat load from 695 to 1568 W/m^2.



a)



b)



c)

Fig. 2. Time dependences of temperatures in the characteristic points, when the filling ratio is equal to 4% and the heat load is: a) q=695 W/m^2, b) q=1088 W/m^2, c) q=1568 W/m^2 (1 is a layer of heat carrier; 2 is a lower boundary of the vapor channel; 3 is a center of the vapor channel; 4 is an upper boundary of the vapor channel).

It should be noted that the steady-state temperature regime was achieved after almost two hours in the entire range of changes in heat fluxes to the evaporation region. This time decreased with increasing heat fluxes. This is most likely due to the accumulation of heat by the liquid heat carrier and material of the thermosyphon case. From Fig. 1, temperature fluctuations were detected when the heat flux is equal to q=1088 W/m^2 and higher. It is due to the fact that N-pentane has a low boiling point (36.1 ° C). When thermal energy is supplied, the evaporation process at "liquid-vapor" interfacial surface is intensified, and there is a fast movement of vapor from the bottom cover to the upper one. These experimental results allow to make a conclusion that there is a high probability of a transition from laminar to turbulent flow during the vapor movement in the vapor channel. An increase in the heat flux after reaching the boiling point of the heat carrier is found not to lead to a significant change in the temperature distribution at the characteristic points. The pressure in the thermosyphon increases with the growth of the heat flux. As a result, saturation temperature of N-pentane also increases.

In conclusion, it should be noted that the observed temperature differences between the evaporation and condensation surfaces in the thermosyphon give grounds for the hypothesis that it is possible to simulate temperature fields in the thermosyphon with a sufficiently high reliability without describing the processes of vapor movement in the vapor channel with the use of sophisticated hydrodynamic models on the basis of the Navier-Stokes equations [12] or the Prandtl model [13].

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