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Experimental study of thermosyphon operation when cooling the condensation part by drop irrigation

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Abstract. The influence of drop irrigation of the condensation part on the thermosyphon operational mode was studied experimentally. The temperature and pressure fall was found in the internal space of the upper chamber after applying the liquid on the upper wall of the thermosyphon. The temperature difference along the height of vapor channel increases and the effective resistance decreases. When complete evaporation of liquid droplets from thermosyphon, it returns to the quasi-stationary mode of operation.

1 Introduction

Two-phase thermosyphons are simple in construction, autonomous, and effective as thermal engineering devices capable of transferring significant heat flows at the minimum temperature differences [1]. Due to these advantages thermosyphons have low operating and capital costs; they are widely used in oil refining, petrochemical and gas industries [2-3], solar energy [4-5], microelectronics and other fields [6, 7]. The operational mode of thermosyphon [8-10] is known to depend on the composition and filling volume of coolant, geometric parameters, inclination angle, material of construction, heat load [11-13], conditions of cooling the condensation part [12]. In this condition, conjugated processes of conduction, convection and phase transitions in thin liquid films or droplets [13-20] are currently poorly studied in order to design energy-efficient heat-removing equipment. To ensure the conditions for safe and efficient operation of these devices, in addition to summarizing the available information, it is necessary to obtain partial dependences of certain factors on the thermosyphon operational mode.

The purpose of this work is to study experimentally the operation of two-phase thermosyphon when cooling the condensation part by drop irrigation.

2 Experimental technique

Experimental studies were carried out on the setup. The scheme of this equipment is presented in Fig. 1.

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The experimental setup consists of the following parts: the test cell 1 has the metal substrate 2, through which heat is transferred from the heating spiral 3 (connected to the power source 4) to the bottom of the lower chamber of the thermosyphon 5. Heat and mass transfer with the change in the aggregate state of the working liquid occurs in the lower chamber of the thermosyphon. The vapors of liquid 7 formed by boiling in the lower chamber pass through the vapor channel to the upper chamber. The condensate 8 flows into the evaporation zone along the walls of the vapor channel.

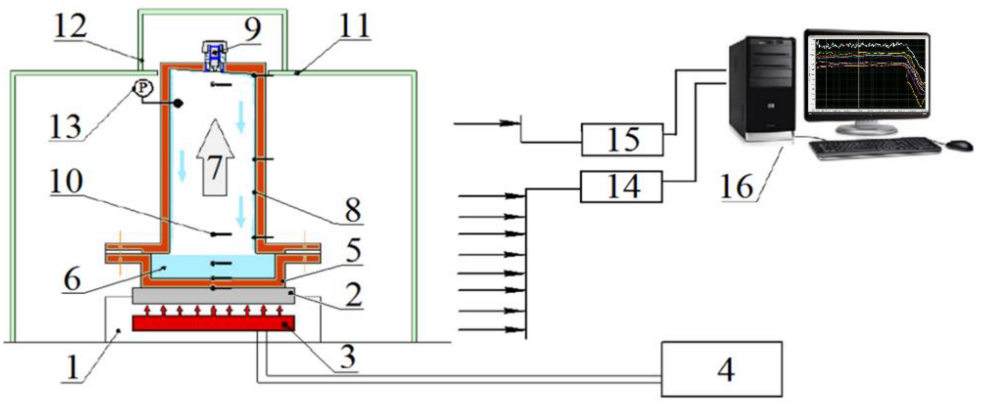

Fig. 1. The scheme of the experimental setup: 1 – test cell; 2 – metal substrate; 3 – heating spiral; 4 – power source; 5 – thermosyphon; 6 – working liquid; 7 – vapors of liquid; 8 – condensate; 9 – valve; 10 – thermocouples; 11 – glass box; 12 – cover for top opening; 13 – pressure sensor; 14 – analog-to-digital converter NI 9214; 15 – analog-to-digital converter NI USB-6000; 16 – personal computer.

The upper wall has a threaded opening for the valve 9, which is designed for pressure control. Eight thermocouples 10 record the temperature: the outer and inner bottom wall of the thermosyphon, working liquid, vapors in the lower and upper part of the vapor channel, condensate on top, center and bottom part of the side wall. To provide constant conditions of the heat exchange, thermosyphon is placed in the glass box 11 with the cover 12 for top opening.

The distilled water was used as the working liquid. After reaching the quasi-stationary mode of the thermosyphon the glass cover was removed from the condensation part, and ten drops of distilled water were uniformly placed on the upper wall of the thermosyphon by Lenpipette dispenser. The volume of a drop was 50 microliters. When complete evaporation of the liquid from the surface, condensation part was covered by the glass cover, and the load increased. The heating power was 6; 7; 9; 11.6 and 14.8 W.

3 Results and discussion

The obtained results of cooling the condensation part are shown in Fig. 2. The temperature and pressure fall was found in the internal space of the upper chamber after applying the liquid on the upper wall of the thermosyphon. At this moment, a sharp increase in temperature difference occurs (Fig. 2).

After evaporation of the applied liquid from the surface there is an increase in the temperature inside the thermosyphon and a decrease in the temperature difference along the height of the vapor channel up to values corresponding to mode without irrigation. So thermosyphon operation returns to the quasi-stationary mode. The irrigation of the condensation part of the thermosyphon does not influence the specific heat flow.

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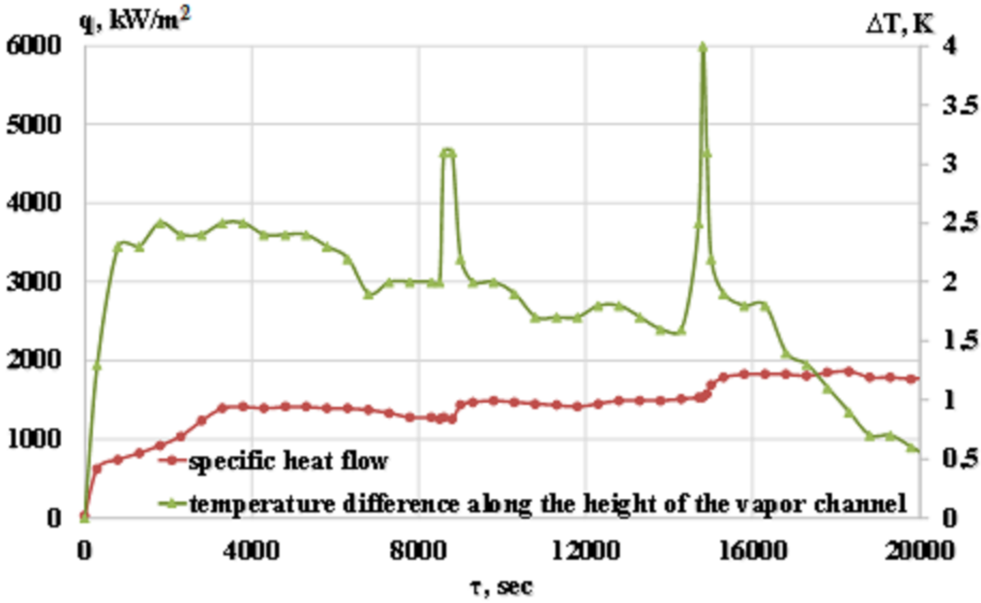

Fig. 2. Change in the specific heat flow and temperature difference along the height of the vapor channel.

The effective thermal conductivity is found to increase with increasing the specific heat flow (Fig.3). When irrigating the condensation part, the effective thermal conductivity decreases.

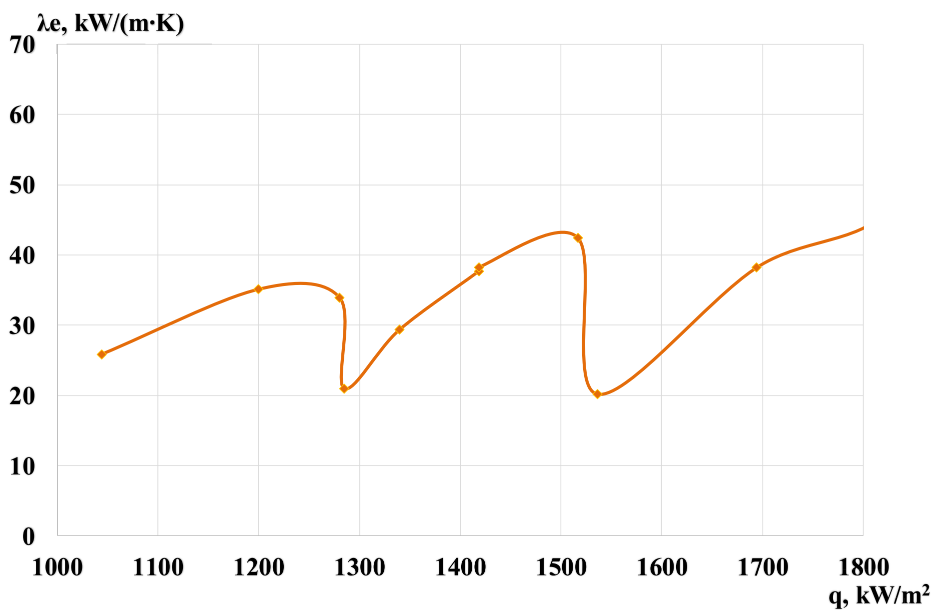

Fig. 3. Dependence of the effective thermal conductivity on the specific heat flow when cooling the condensation part.

It is connected to the fact that when evaporating the liquid drops from the top wall of the thermosyphon, heat equaled to the latent heat of vaporization is assimilated. The temperature in the upper part of the thermosyphon dramatically decreases, as a result, the temperature difference along the height of the vapor channel increases. This leads to an increase in the effective resistance. Since the effective thermal conductivity and resistance are inversely proportional, the latter one decreases.

When complete evaporation of liquid drops, the surface temperature and effective thermal conductivity increases, the temperature difference inside the thermosyphon decreases, and it returns to the quasi-stationary mode of operation.

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