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OPERATION OF THERMOSYPHONS AT SMALL ANGLES OF INCLINATION TO THE HORIZONTAL

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Thermosyphons with internal coaxial inserts in the heating zone are investigated. Their operation at small angles of inclination to the horizontal is analyzed. The optimum design of the inserts that ensures operation of the thermosyphons at an angle of inclination of 5° is determined.

Thermosythons are very efficient heat-conducting devices whose use under terrestrial conditions is preferable to classical heat pipes with a completely "wicked" internal surface. There are the following reasons for this: thermosyphons are simpler to manufacture and are less expensive than heat pipes; the thermal resistance of a thermosyphon is lower than that of a heat pipe (the wick in the condensation zone of a heat pipe thickens the liquid film and decreases the intensity of heat transfer). In view of this, evaporative two-phase thermosyphons are finding increasing use in industry for the cooling and thermal stabilization of various objects. At the present time thermosyphons with a smooth heating zone have been studied sufficiently well. However, classical thermosyphons have an important drawback, namely, their operation at small angles of inclination to the horizontal is very unstable [1]. As a result, a sharp increase in the mean temperature of the heating zone surface of the thermosyphon occurs and ultimately the overheating of the device being cooled by it turns out to be above the admissible one.

Below, experimental results are reported for thermosyphons with various coaxial inserts in the heating zone, which are intended for both enhancing heat transfer and ensuring for the most part their stable operation at small angles of inclination to the horizontal. It is known [2] that at angles of inclination smaller than 45° an internal annular insert in the heating zone ensures stable operation of a thermosyphon.

The thermosyphons investigated were made of copper and were filled with distilled water. Thermosyphons with air and water cooling of the condensation zone were investigated. The length of the thermosyphons was 250 mm (the length of the heating zone was 60 mm), and the diameter was equal to 20 mm. The heating zone was furnished with two fins to which heat sources simulating the device being cooled were attached. In Fig. 1 the coaxial inserts installed in the heating zone of the thermosyphons are shown. The characteristics of the thermosyphons investigated and the geometric parameters of the inserts are given in Table 1. The repelling ring [3] located in the transport zone somewhat above the heating zone is the simplest separator that prevents in large measure the entry of liquid into the condensation zone from the annular gap in the heating zone. The charge volume of the thermosyphon was determined according to the recommendations given in [4]. The condensation zone was cooled by a heat carrier having a temperature of the order of 50°C.

In Fig. 2 curves that make it possible to judge the effect of the type of insert in the heating zone on the temperature drop ΔT between the surface of the simulator and the cooling medium are presented. By choosing the simulator temperature as the basic one, it is possible to obtain experimental data that can easily be used in practice, since the usual use of the heating zone surface temperature for this purpose brings complexities into the calculations of the true temperature of the device being cooled due to uncertainty in the thermal resistance of the system of the device and the surface of the thermosyphon. It is seen from the figure that with a vertical disposition of the thermosyphon the inserts of type 1 and 2 turned out to be the most efficient (see Fig. 1), as they promote at most the turbulization of the vapor-liquid mixture in the annular gap. Thus, inserts with fins on the unheated surface turned out to be more efficient than hydrophobic (Fig. 1, item 4) and netlike inserts.

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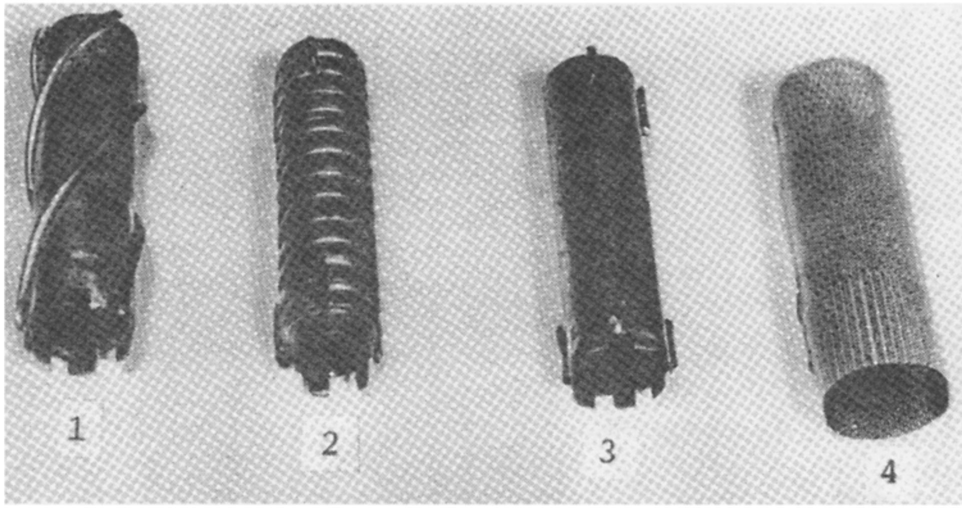
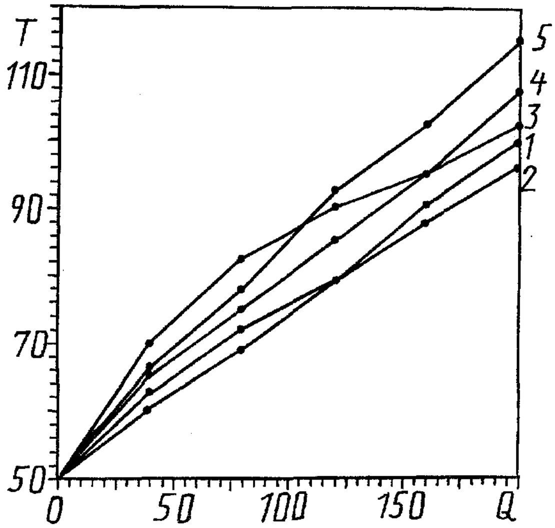


Fig. 1. Construction of coaxial inserts in the heating zone of thermosyphons: 1, 2, 3, 4) inserts 1, 2, 3, 4, respectively, in Table 1.

TABLE 1. Geometric Characteristics of Inserts

No. of insert (see Fig. 2)	Geometric characteristics of internal inserts	Volume of filling, g
1	Annular insert with three spiral fins. Diameter 14.5 mm, height 59, outer diameter of fins 18, fin pitch 1.5 mm. A repelling ring is installed in the transport zone	11
2	Annular finned insert in the zone of heating. Diameter 14.5 mm, height 59, fin pitch 4.5 mm, width of fins 2, height of fins 0.75 mm. A repelling ring is installed in the transport zone	11
3	Annular smooth insert in the zone of heating. Diameter 14.5 mm, length 59 mm. A repelling ring is installed in the transport zone	11
4	A perforated fluoroplastic insert is installed without a gap in the zone of heating. The thickness is 0.15 mm, diameter of perforations 0.7 mm, porosity 0.48 mm. The bushing is pressed to the heating surface by a 0.1-mm-thick nickel foil band with a similar perforation. A repelling ring is installed in the transport zone	11
5	A two-layer wick made of stainless steel Kh18N9T is installed in the zone of heating. The lower layer is a grid of serge netting No. 008, the upper layer is a grid of serge netting No. 014 according to Specs. (TU) 14-169-68-78	6

When the angle of inclination to the horizontal is decreased, the heat-transmitting characteristics of thermosyphons with some types of inserts are improved (Fig. 3) and in some cases exceed the values characteristic for the vertical position of the thermosyphon. Furthermore, thermosyphons without internal inserts do not operate at inclination angles smaller than 10° because of drying of a large portion of the heating zone. The fact of an improvement in the operation of a thermosyphon with a decrease in its inclination to the horizontal is well-known [1]. This is associated with both a decrease in the thickness of the liquid film in the condensation zone and a reduction in the area of interaction of the liquid and vapor flows moving opposite each other.



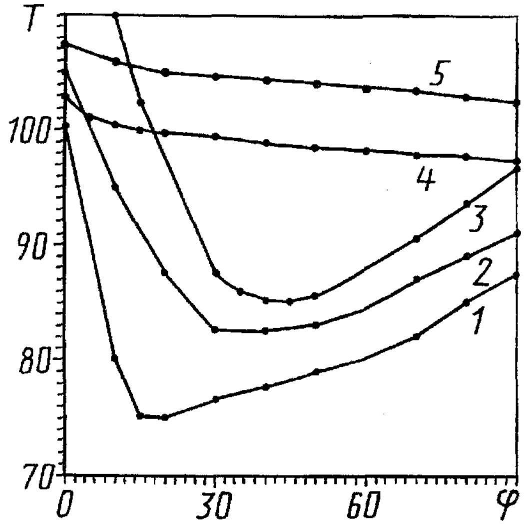


Fig. 2. Temperature of the simulator T (^{o}C) vs released heat flux Q (W) at an angle of inclination of the thermosyphon to the horizontal φ of 90^{o}: 1, 2, 3, 4, 5) inserts 1, 2, 3, 4, 5, respectively, in Table 1.

Fig. 3. Effect of the angle of inclination of the thermosyphon inclination φ to the horizontal on the temperature T of the simulator at a heat flux Q of 160 W: 1, 2, 3, 4, 5) inserts 1, 2, 3, 4, 5, respectively, in Table 1.

From Fig. 3 it is seen that the coaxial insert with transverse fins turned out to be the most efficient at small angles of inclination to the horizontal (see Fig. 1, item 2). The fins on the surface of the insert and the wall of the thermosyphon form annular channels in which the boiling liquid climbs up and flows over the entire surface of the heating zone at small angles of inclination of the thermosyphon to the horizontal. Similar effects but less expressed are also observed with the use of an insert of type 1 (Fig. 1). The inserts indicated turned out to be more efficient that netlike or perforated ones, in which the liquid is transported to the upper part of the heating zone by capillary forces. For inserts of the last type (see Table 1, types 4 and 5; Fig. 1, item 4) ΔT depends weakly on the angle of inclination in a wide range of variation for it, and this permits one to use them in cases where it is necessary to maintain constancy of the temperature of the cooled device with a change in its orientation in space in the process of operation.

Thus, the present investigation has shown that a coaxial insert with transverse fins is the most efficient, since it ensures admissible temperature regimes of the cooled device at angles of inclination to the horizontal from 90 to 5^{o}.

NOTATION

T, temperature of the simulator; Q, heat released by the simulator; φ, angle of inclination of a thermosyphon to the horizontal.

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