A PROMISING SYSTEM FOR ELECTRONIC MODULE COOLING BASED ON PULSATING HEAT PIPES*

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Modern electronic systems include a large number (sometimes up to several thousand) of powerful electronic modules. When the efficiency of powerful electronic components (transistors, microcircuits, etc.) is 25…40 %, a significant part of the electrical energy consumed by the electronic module is converted into heat. As a result of an increase in the temperature of active electronic components, their reliability and the reliability of the electronic module as a whole are reduced. In this connection, the development of effective cooling systems for electronic modules of various purposes remains an urgent problem.

The purpose of this work is to develop a new effective air-cooling system for the electronic module based on highly efficient two-phase heat transfer devices – pulsating heat pipes (PHPs), which operates in a wide range of ambient temperatures, from –50 to +50 °C.

For this purpose, The National Technical University of Ukraine "Ihor Sikorskyi Kyiv Polytechnic Institute" has developed a new promising design of a cooling system based on PHPs [1], which can be used to remove heat from the transmit/receive modules of radar stations. The structural diagram of the cooling system is shown in Figure 1. Base 1 of the cooling system is made of aluminium alloy. Its mounting surface accommodates powerful transistors 2, and cooling fins 8 are located on the heat exchange surface.

Effective removal of heat from powerful transistors 2 to cooling fins 8 is carried out using zigzag-shaped PHPs 6 and 7 with interconnected ends. Liquid coolant located in the evaporation zones 11 and 12 of the PHP begins to boil, while intensively absorbing the supplied heat. An increase in vapour pressure in the evaporation zones leads to the formation of a pulsating movement of a vapour-liquid projectiles in the condensation zones 9 and 10 of the PHP, owing to which the heat flow with a minimum thermal resistance (0.1…0.5 ºC/W) is effectively transferred along the length of the PHP to all cooling fins 8, regardless of their location.

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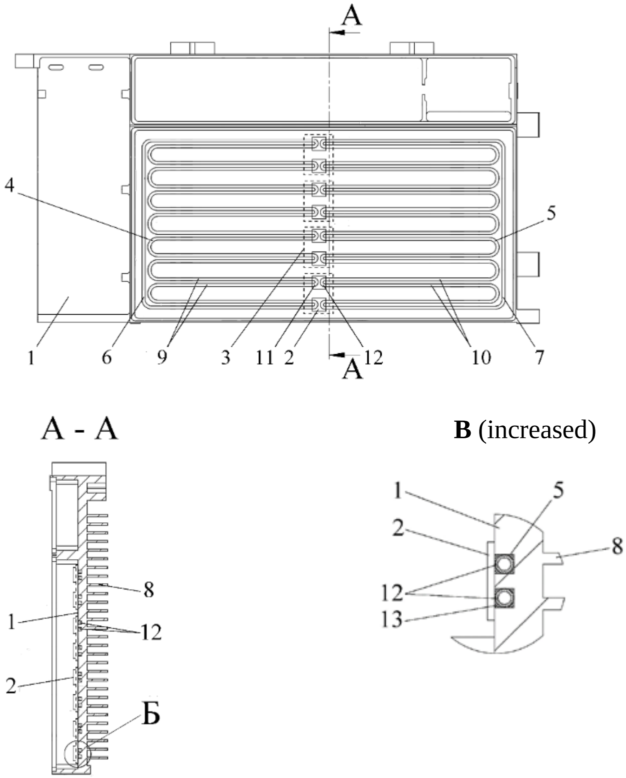


Figure 1. System for electronic module cooling based on PHPs:
1 – base; 2 – heat-releasing element; 3 – board with two elements;
4, 5 – open channels; 6, 7 – PHPs; 8 – cooling fin;
9, 10 – PHP condensation zone; 11, 12 – PHP evaporation zone;
13 – heat-conducting glue

Since the operating temperature range of the electronic module can be very wide, for instance, from –50 to +50 °C, for the PHPs of the cooling system one should choose coolants with a low melting point (see Table 1).

Thermal characteristics of a PHP depend on many factors, in particular, on its inner diameter and thermophysical properties of the coolant. Since there is no data in the literature on the operation of the PHP with the specified coolants at low operating temperatures, for the design of the cooling system it is important to determine the range of values of the PHP inner diameter, which ensures a stable pulsation-projectile in the PHP.

Table 1

Characteristics of possible freons for PHPs

Coolant	**Freon 123**	**Freon 134a**	**Freon 141b**	**Freon 142b**
Formula	$C_2HCl_2F_3$	C_2HF_4	$C_2H_3Cl_2F$	$C_2H_3ClF_2$
Melting point, °C	–107.15	–103.30	–103.30	–130.43
Boiling temperature, °C	27.82	–26.07	32.05	–9.15

Source: [2, p. 627–628]

It is shown in [3] that in order to maintain a stable pulsation-projectile mode in the PHP, its inner diameter *D* must meet the condition:

$$D \leq 2 \cdot \sqrt{\frac{\sigma}{g \cdot (\rho_l - \rho_\upsilon)}}, \tag{1}$$

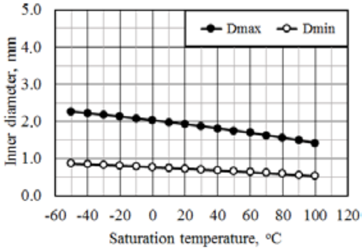
where σ is the coefficient of surface tension, N/m; g – 9.81 m/s^2; ρ_l and ρ_υ are the density of liquid and vapour of the coolant, respectively, kg/m^3. In [4], it is proposed to choose a narrower range of values of the PHP inner diameter, namely, from the maximum value D_{max} to the minimum D_{min}, defined as:

$$D_{max} = 1{,}84 \cdot \sqrt{\frac{\sigma}{g \cdot (\rho_l - \rho_\upsilon)}}, \tag{2}$$

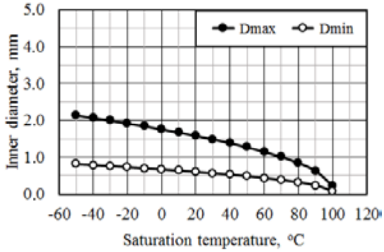
$$D_{min} = 0{,}7 \cdot \sqrt{\frac{\sigma}{g \cdot (\rho_l - \rho_\upsilon)}}. \tag{3}$$

With regard to the temperature dependence of the thermophysical properties σ, ρ_l and ρ_υ of the coolant, using formulae (2) and (3), we have constructed the graphical dependences necessary for the design of the cooling system to find the inner diameter of PHPs operating in a wide temperature range (Figure 2). The expansion of the upper temperature range to +100 °C on the graphs is due to the possibility of reaching such temperature values by the coolant vapour when PHPs are operating under a high thermal load at an air temperature of +50 °C.

The given graphic dependences can be used to choose the diameter of pulsating heat pipes when designing a new advanced cooling system, for instance, for transmit/receive modules of antenna systems of radar stations.



Freon 123



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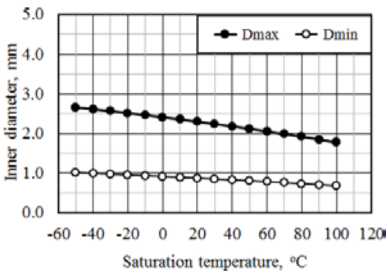

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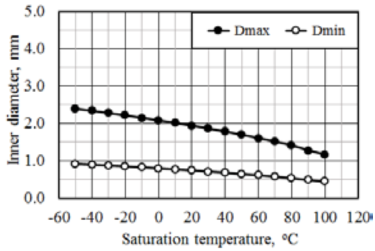

Freon 142 b

Figure 2. Dependence of the maximum D_{max} and minimum D_{min} values of the PHP diameter on the pressure of saturated vapour of freons

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