INFLUENCE OF ADVERSE ACCELERATIONS ON THE
OPERATION OF AN "ANTIGRAVITY" HEAT PIPE

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The authors present results of an experimental investigation of the influence of accelerations directed along the heat-transfer vector on the operation of heat pipes with separate channels for vapor and liquid.

There is a considerable gulf between the capability of elements of electronic equipment (EE) and heat pipes (HP) to function under the action of vibrations, accelerations, and other factors unfavorable for heat pipes. The literature has practically no information on the operation of heat pipes under the action of dynamic, arbitrarily directed accelerations of more than 1g.

The case of heat transfer in the direction of the vector of the accelerations acting on the heat pipe is more complex for the operation of a heat pipe, since it requires added expenditure of energy to move the liquid heat transfer agent into the heat supply zone against the action of mass forces.

The hydrostatic pressure can be compensated for by increasing the capillary potential due to a reduction of the size of pores of the heat pipe wick, which in turn leads to a...
sharp increase of the hydraulic resistance of the capillary pump and a considerable decrease of the heat flux transferred. Therefore, the use of heat pipes with a capillary-porous structure located along the entire length of the heat transfer is of low efficiency in a variable field of mass forces.

In heat pipes with separate channels for vapor and liquid, which have been called anti-gravity heat pipes (AGHP), the hydraulic resistance of the wick is substantially reduced by locating it only in the heat supply zone, so that the heat and mass fluxes in the wick of an AGHP are directed opposite to one another [1, 2]. Here the path length of the liquid heat-transfer agent along the capillary channels of the wick is considerably less than the heat-transfer length in a heat pipe, and is several millimeters. This circumstance leads to the fact that the necessary capillary potential to operate AGHP's is used not so much to drive the liquid heat-transfer agent along the fine pores of the wick as to overcome the hydrostatic pressure of the column of liquid in the heat pipe. Thus, the first condition for operability of an AGHP in the field of mass forces can be written in the form

$$\Delta P + \rho aL \sin \varphi \leq \frac{\Delta \sigma \cos \Theta}{d_p}. \quad (1)$$

The pressure balance condition in an AGHP is necessary but not sufficient to ensure its operability.

To move the heat-transfer agent from the heat supply zone (Fig. 1) to the compensation cavity requires a specific pressure difference. This required pressure difference is achieved by capillary forces, but is formed by the difference of the temperatures of saturated vapor in the heat supply zone and the compensation cavity:

$$P_v - P = (\Delta P - \Delta P_{IW}) + \rho aL \sin \varphi \approx \frac{dP}{dT} \left[ T_v - T \right]_{T_v + \tau_{v/2}}. \quad (2)$$

The driving temperature head $\Delta T_\varphi = T_v - T$ forms when a heat flux is supplied and is determined by the conditions of heat and mass transfer through the wall of the wick of an AGHP, seen in the role of a hydraulic and thermal gap between the evaporation zone and the compensation cavity. The driving temperature head $\Delta T_\varphi$ is a necessary contribution to the thermal resistance of an AGHP.

When one analyzes the operation of a heat pipe in a mass force field with an adverse orientation ($\sin \varphi > 0$), the degree to which the capillary forces exceed the mass forces can be described by the Bond number (Bo):

### TABLE 1. Some Parameters of AGHP Heat-Transfer Agents for $a = 10g$ and $d_p = 2 \times 10^{-6} m$

<table>
<thead>
<tr>
<th>Heat-transfer agent</th>
<th>$\rho$, $N/m^3$ at $T = 50^\circ C$</th>
<th>$\rho$, $kg/m^3$ at $T = 25^\circ C$</th>
<th>$\frac{dP}{dT}$, kPa/K, For $T = 50^\circ C$</th>
<th>$\Delta P_{\text{max}}$, kPa, For $T = 50^\circ C$</th>
<th>$\Delta T_\varphi$, K</th>
<th>Bo</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Pentane</td>
<td>1.3</td>
<td>621</td>
<td>3.8</td>
<td>26</td>
<td>4.80</td>
<td>0.72</td>
</tr>
<tr>
<td>Acetone</td>
<td>2.0</td>
<td>785</td>
<td>2.8</td>
<td>40</td>
<td>8.40</td>
<td>0.58</td>
</tr>
<tr>
<td>Freon-11</td>
<td>1.5</td>
<td>1475</td>
<td>6.6</td>
<td>30</td>
<td>1.42</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>1.6</td>
<td>502</td>
<td>72.0</td>
<td>32</td>
<td>0.23</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Fig. 1. Schematic diagram of a heat pipe: 1) evaporation chamber; 2) vapor discharge channels; 3) wick; 4) compensation cavity; 5) thermocouple; 6) vapor channel; 7) condensation channel; 8) condenser; a) vapor discharge channels in the heat supply zone.