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# INFLUENCE OF WORKING POSITION FOR THERMAL PERFORMANCE OF THE CAPILLARY HEAT PIPE

**Abstract**

*This experiment is concentrated on working position for optimization of capillary heat pipe. The main objective was to find optimal working position for capillary heat pipe. Working position is an important part for function of the heat pipe. A change in working position should change thermal performance of capillary heat pipe.*

**Keywords**:capillary heat pipe, thermal performance, working position

## 1. Introduction

Increasing performance and number of electronic components will be a problem with regard to cooling of these elements. This problem is concerned with heat flow. Perfect cooling of these components ensure longer time of operation of equipment and full device. How to effectively take heat flow from heat pipe surface is the main problem. The biggest heat flow is produced by the change of phase, namely by boiling and condensation. The concept of the modern heat pipe was first put forth by R.S. Gaugler of General Motors Inc. in 1944. He added the idea of using a wick to make the inner fluid return back to the evaporator instead of gravity. Capillary heat pipes are used in the space industry for cooling and heat transfer in solar devices. Capillary heat pipe are capable of passive cooling with free convection. This phenomenon is often made use of in electronics components.

The aim of the experiment is to compare the cooling effect depending on working position. Heat pipes in terms of working position are universal. Heat pipe is a heat transfer device that combines the principles of both thermal conductivity and phase transition to efficiently managing the transfer of heat between two solid interfaces. Majority of heat pipes use a wick and capillary action to return the liquid from the condenser to the evaporator. The liquid is sucked up to the evaporator, similar to the way that a sponge sucks up water when an edge is placed in contact with a water pool. The wick allows the heat pipe to operate in any orientation [1, 2, 3]

They can work against gravity. No need to pay attention to the source location, because the tube is able to automatically adjust its stable operation mode. The capillary system may be different on the inner side. Similar to the gravity heat pipe is capillary heat pipe. It is important for heat transfer liquid to flow from the condenser to the evaporation section. Thermal resistance of phase transformations in the production of steam in capillary heat pipe can be neglected. Transport condensate is different than in gravity tubes.

## 2. Design of capillary heat pipe

We chose a method of measuring with water for experimentally measurement the performance of the heat pipe. We built a capillary heat pipe. Capillary heat pipe was filled with a certain amount of working medium (25%) at pressure of 80Pa. Capillary heat pipe material is copper. Its length is l=50 cm and the external diameter d=15 mm while internal diameter 13 mm. The inner wall of the capillary heat pipe was covered with stainless steel mesh with mesh

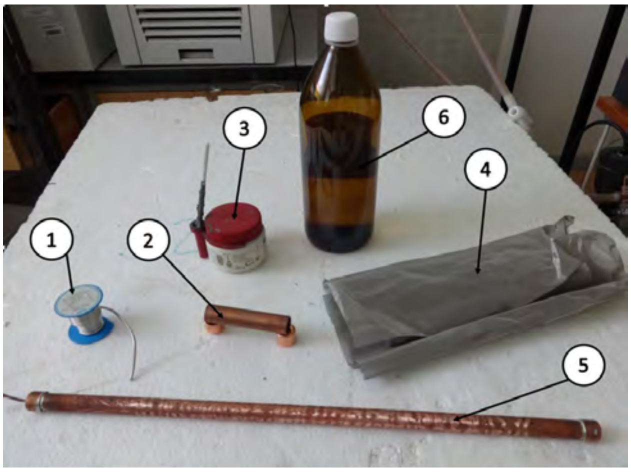

Fig. 1. Heat pipe device components: 1 – tin wire, 2 – cooper pipe and fittings, 3 – tin paste, 4 – steel grid, 5 – capillary heat pipe, 6 – working medium 96% alcohol

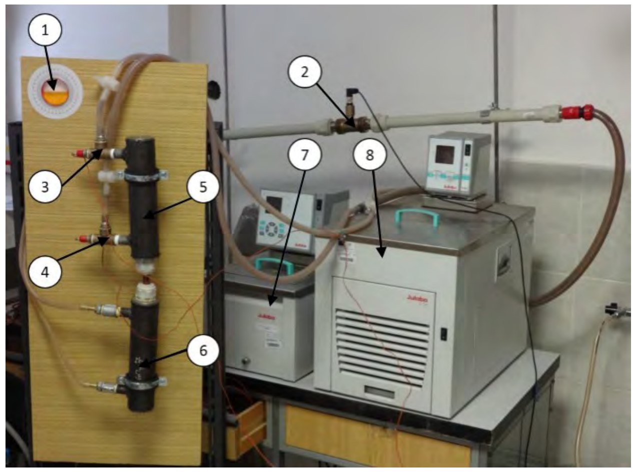

Fig. 2. Involvement of the capillary heat pipe: 1 – protractor, 2 – flow meter, 3 –- outlet temperature, 4 – inlet temperature, 5 – condenser, 6 – evaporator, 7 – water heating for evaporator, 8 – cooling water for condenser

number 200, mesh size 0,075 mm, wire diameter 0.05 mm. Heat pipe is hermetically closed. We used the program AMR WinControl from AHLBORN for recording the measured values. During measurements constant heating for the evaporation of the heat pipe was achieved by flowing water at the temperature of 80°C and a condensing part of the water flowing at 15°C. For experimental measurements of temperature at inflow and outflow of water were recorded for the condenser and the flow medium [4, 5]. Heat pipe device components have been presented in Figure 1 while the experimental set-up in Figure 2. Amount of working medium was 16,59 ml. In order to calculate the correct amount of working fluid equation (1) was used.

$$V_{alcohol} = \frac{\pi d^2}{4} l \frac{x}{100} \quad (m^3) \qquad (1)$$

where x is percentage of working medium %, l – length m, d – diameter m.

## 3. Experimental measurement and evaluation of measured values

We chose the calorimetric equation (2) for obtaining the results of thermal performance capillary tube, which describes the heat transfer bodies, forming isolated system, covered by the law of conservation of energy. The law of conservation of energy is that all the heat that is exchanged by a single body transfer, the second body receives. We can suppose that there is no change in the type of energy, heat energy cannot be changed, for example into mechanical energy, and the substances are chemically inert, generating no heat from chemical reactions [6].

$$\dot{Q} = \dot{m} c \Delta T \quad (W) \qquad (2)$$

where m is the mass flow rate kg/s, c is specific thermal capacity J/(kgK) and ΔT is the temperature difference K.

The mass flow rate can be obtained from the following:

$$\dot{m} = \rho \dot{V} \quad (kg/s) \qquad (3)$$

where ρ is density kg/m$^3$ while and V – volumetric flow rate m$^3$/s

The results of the measurements have been given in Table 1 and Figure 3.

Tab. 1. Experimental results.

| Angle | 0° | 15° | 30° | 45° | 60° | 75° |
|---|---|---|---|---|---|---|
| Thermal performance | 269.012 W | 286.130 W | 300.364 W | 293.948 W | 255.37 W | 286.193 W |
| 90° | 105° | 120° | 135° | 150° | 165° | 180° |
| 200.661 W | 131.767 W | 131.440 W | 145.481 W | 99.892 W | 99.480 W | 99.069 W |

environment

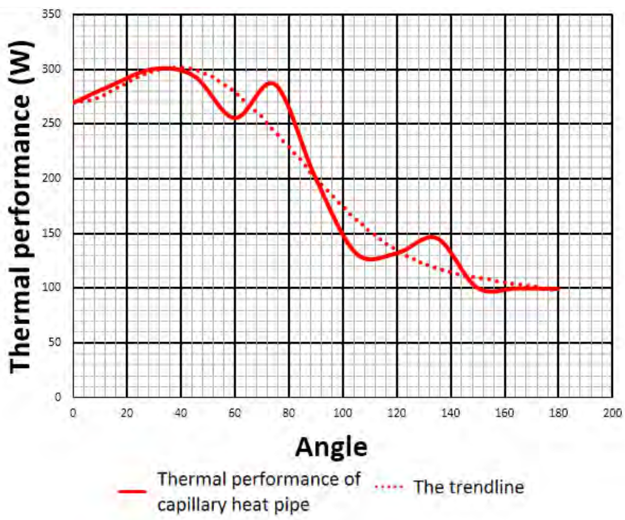


Fig. 3. Thermal performance of the heat pipe.

The trendline equation takes the form of:

$$y = 2E - 10x^6 - 1E\text{-}07x^5 + 3E\text{-}05x^4 - 0.0034x^3 + \\ + 0.126x^2 - 0.5406x + 270.97$$

while the value of reliability of this equation fitting is $R^2 = 0.9483$.

## 4. Conclusions

This experiment dealt with the influence of the working position on the thermal performance of the capillary heat pipe. The experimental measurements and calculations show the worst position is where condensation is under evaporator. The best results are where capillary heat pipe is inclined at an angle of 30°. At this angle the thermal performance was measured as 300.36 watts. Measurements confirm that capillary heat pipes are universal and independently from the working position. In the graph of the results the trendline was carried with the trendline equation for calculating thermal performance at any working position. Accuracy this trendline equation is 0.9483, comparing to the best accuracy of 1, it is very accurate.

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## References:

[1] Faghri A. *Heat Pipe Science and Technology*. Washington DC. Taylor & Francis, 1995.
[2] Reay D. A., Kew P.A.: *Heatpipes, Theory, Design and Applications,FifthEdition*, USA, 2006.
[3] Ochterbeck J.M.: *Heat pipes, In Heat Transfer Handbook*. 2003.
[4] Lenhard R., Kaduchová K., Jandačka J.: *Numerical simulation of indirectly heated hot water heater*. 2012 International Conference on Advanced Material and Manufacturing Science
[5] Lenhard R., Jandačka J.: *Two-phase modeling of interphase heat transport from the condensation to evaporation part of the heat-pipe*. 11th International Conference of Numerical Analysis and Applied Mathematics 2013
[6] Čaja A., Kolková Z., *Vplyv konštrukcie chladiča na schopnosť odvádzania tepla z kondenzačnej časti tepelnej trubice*,. stretnutie katedier mechaniky tekutín a termomechaniky, 2013. Acknowledgement