# The Possibility of Electronic Equipment Cooling

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*Abstract* — **Cooling has a large and irreplaceable importance in electronics and its solution is a part of the technology design and construction of any real device. Due to the progressive miniaturization and increasing performance we can meet cooling more often in consumer electronic products. In addition to many well-known conventional methods of cooling there is a possibility to use a high-capacity heat transport device - heat pipe. A disadvantage in some applications is the restriction of the possibility to control the thermal conductivity. The authors have dealt with so far little explored possibility of control using an external magnetic field with magnetic fluid as the heat pipe workload. The system is reversible in terms of control and uses the unique features of magnetic fluids.**

*Keywords — Cooling, heat pipe, magnetic fluids, thermal conductivity.*

## I. INTRODUCTION

Heat transport (in terms of physical nature) is done by three basic mechanisms – conduction, convection and radiation, which are in most cases combined with each other. The heat pipe is in principle a closed two-phase system in which heat transfer is realized by continuous and rapid circulation of steam and liquid phases and phase transformations of each other – evaporation and condensation of working fluid. One end of the tube is usually thermally and mechanically connected to the heat source and the other end ensures removing of the heat transferred by tube. Liquid evaporates in the evaporation section and in form of steam flows into the condenser section, where in contact with the inner surface of the tube cooler condenses to a liquid phase. The liquid condensate then runs down or flows on the walls tube back into the evaporation section.

## II. ONE OPTION IS HEAT PIPE

Heat pipe elements are intended for highly efficient transport of heat, a intense development was stimulated in the middle of last century, particularly in connection with the space programs in the U.S. where they had to be dealt with problems of heat transport in the specific space conditions (high vacuum, weightlessness). Currently,

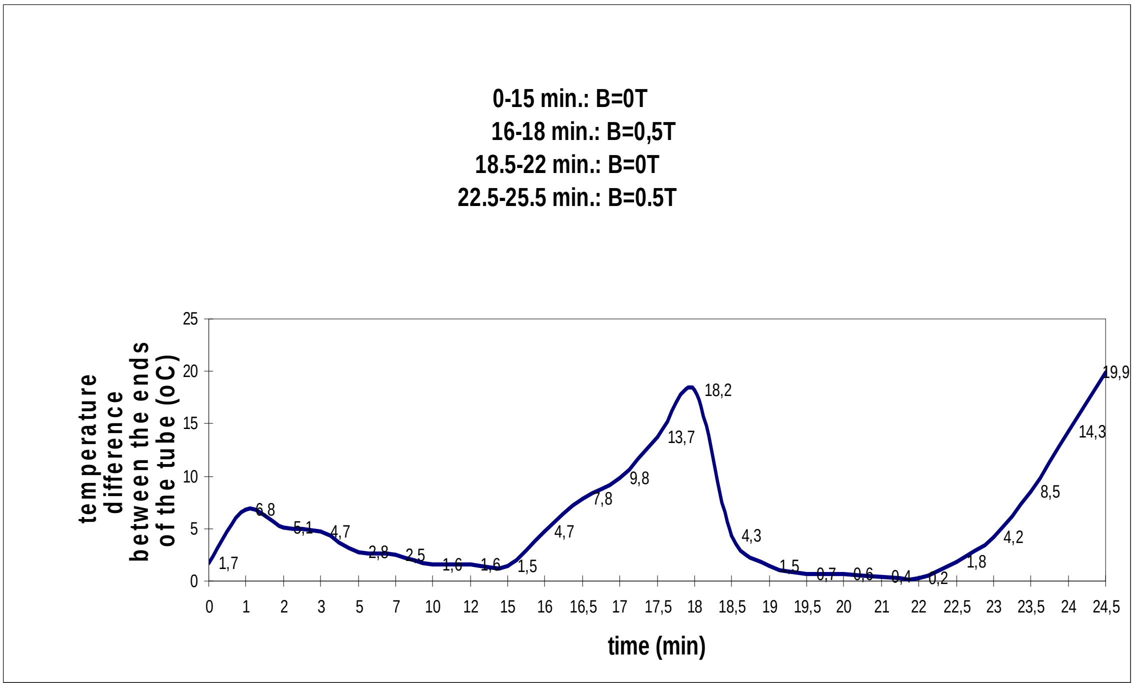


*Fig. 1: Temperature difference between the ends of the tube*

heat pipes have a common alternative to conventional methods of the heat transfer in many devices used in various areas of life. Outwardly, the heat pipe behaves as a solid body made of a material of extremely high thermal conductivity λ (of the order to $10^4$ $Wm^{-1}K^{-1}$), significantly higher than for example copper (380 $Wm^{-1}K^{-1}$) and is able to transfer heat so intensive even at relatively low temperature gradient. Due to its simple construction, reliable operation, the availability of a suitable type and price, heat pipes are used now in a wide area of applications, such as elements of power electronics cooling, heat recovery, ensuring of the thermal dynamics of selected technological and biological processes, cooling, solar panels and many others.

## III. The Design and Types of Heat Pipes

In heat pipe called as *gravitational* the condensate is transported by earth gravity. The working substance in the liquid phase flows down the walls of the tube in form of a thin film to evaporator section. Precondition of functionality for this type of the tube is a configuration with a warm end placed below the cool end of the tube. The tubes can be oriented vertically or at an angle, the performance of the heat pipe in this case is influenced by the slope and specific weight of the condensate.

In case of *capillary* tubes their function is not significantly depending on the orientation in a gravitational field, since the condensate is transported mainly by capillary pressure, resulting in contact of the liquid phase and a suitably chosen capillary system. In this case, along the inner wall of the capillary tubes the system is located, usually consisting of a groove system, sieves and fibers.

To increase the heat output of tubes it is sometimes used a combination of several types of capillaries, such as grooves in the tube wall and several layers of sieves. Although the capillary tubes compared with the gravitational ones are more complicated, there are today the most widespread in many applications mainly due to ensuring functionality in all positions.

## IV. Experimental Heat Pipe with Controlled Heat Transport by Magnetic Field

### A. Description and characteristic

This is an experimental gravity type heat pipe which, can operate in a uncontrolled mode - that is the maximum heat transport (maximum equivalent thermal conductivity) or under a control with external static magnetic field - that is the limited transport of heat (lower thermal conductivity equivalent). The working substance in this case is the magnetic fluid in form of dispersions composed of pure water and specially prepared $Fe_2O_3$ nanoparticles.

The present sample uses unique properties and behavior of magnetic fluid in a magnetic field for effective influence of the continuous opposite flow intensity of steam and condensate between the ends of the tube where the heat is conveyed (evaporator) and where heat is removed outside.

Application of an external magnetic field of sufficient level (induction B) in properly selected position between the evaporator and condenser of vertically placed tube caused an imbalance between the amount of evaporated and condensed returning substances. It causes a disruption of the continuity of the internal flow, which is externally indicated by a temperature difference between evaporator and condenser - temperature will increase (decrease the equivalent thermal conductivity of the tube).

Based on this principle it is possible to control, using an external magnetic field, temperature between the evaporator and condenser or almost interrupt thermal binding between one part and the second part of the tube (evaporator - condenser) - it looks as the "thermal key".

The situation is well illustrated in Fig. 1, where the difference between evaporator and condenser heat pipes on time is drawn in the dependence of the measured temperature.

It is illustrated gradually for 4 situations where the external magnetic field was not applied along the tube (B = 0 T) and when it was applied (B = 0.5 T). Measurements were performed at ambient temperature + 22.8 °C, with attached external thermal insulation and with natural cooling by surrounding air.

### B. The arrangement and main technical parameters

- Case is made of clear glass tube. On the bottom side is the evaporator with an external resistive heating, on the upper side is the condenser with an external cooler. Temperature is measured by a thermocouple type K.
- Tube length is 350mm, tube diameter is 9mm, glass thickness is 1mm.
- Induction of a permanent magnet is B = 0.5 T (two magnets NeFeB against each other, dimensions 40x20x10 mm, gap width 12 mm).
- Pipe heating power is 10W.
- Operating temperature range is about +20 ° C to +70 ° C.
- Working substance is water + magnetic fluid Ferrotec with the proportion 1:1, the total quantity of the working fluid is 2.5 ml.
- Operating pressure in the tube is about 2.5 kPa.

The actual appearance of the equipment is shown in Fig. 2. A detail of the tube inserted in the magnetic field during heating is shown in Fig. 3. Circulation of the workload is interrupted at this location.

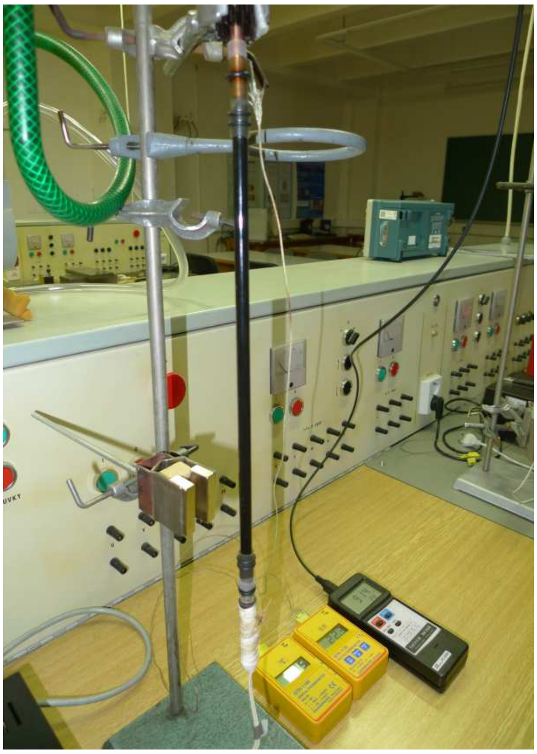

*Fig. 2: Actual appearance of the equipment*

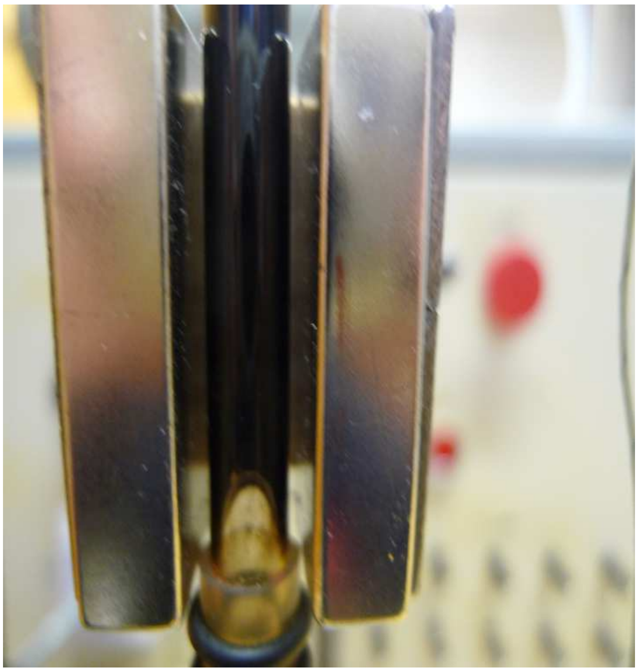

*Fig. 3: Detail of the tube in the magnetic field*

## V. Conclusion

In this paper the authors describe realized functional sample of the thermal heat pipe which is an original contribution to the development of new types of heat pipes with improved properties and to other magnetic fluid usability in practical applications. There were verified the functionality of the sample in experiments but there were not solved purely operational matters such as reliability and durability. Using magnetic fluid as the working fluid in heat pipes with controlled heat transport is minimally explored area, but due to the possibilities of a widespread use in practical applications, a very promising area.

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## References

[1] Cingroš, F., Hron, T., Kuba, J.: Magnetic Field Control of Cryogenic Heat Pipes. In *Proceeding of the International Conference ISSE 2009.* Brno (Czech Republic), 2009.

[2] Ueno, S., Iwaki, S., Tazume, K.: Control of Heat Transport in Heat Pipes by Magnetic Field. *J. Appl. Phys*., Vol. 69 (1991), No. 8, p. 4925 – 4927.

[3] Cingroš, F., Hron, T.: Working Fluid Quantity Effect on Magnetic Field Control of Heat Pipes. In *Acta Polytechnica,* Vol. 49, No. 2-3/2009, ISSN 1210-2709, p. 44-47.

[4] Cingroš, F., Hron, T., Kuba, J.: Investigation and Diagnostic of Magnetic Control of Cryogenic Heat Pipes. In *Electroscope*, No. 5/2011, ISSN 1802-4564, ZCU Plzen.

[5] Kuba, J., Cingroš, F: Experimental Heat Pipe Controlled Heat Transport by Magnetic Field, *Registered Functional Sample No. 13113/5/2011*, CTU in Prague, Faculty of Electrical Engineering, Department of Electrotechnology.

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