INFLUENCE OF TEMPERATURE ON DIELECTRIC BREAKDOWN OF WORKING FLUID VAPOR IN HEAT PIPE

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Abstract: *The paper deal with heat pipe technology which is often used in electronic cooling from small voltage microchips to the high voltage electric elements. In case of cooling the high voltage electric elements have to be evaporator part and condenser part of heat pipe a separated by electrical nonconductive material, because the heat pipes are most often made of metallic materials, and thus, are electrically conductive. As a working fluids in this applications are used dielectric fluids such as fluorinert liquids. But there is still risk of the dielectric breakdown between evaporator and condenser of heat pipe. The task of the experiment is to find how the ambient temperature effect on dielectric breakdown of vapour phase of working fluid in heat pipe. In experiment was investigated dielectric breakdown between copper pipes inserted in to glass heat pipe in distance of 70 and 65 mm and temperature range -10 to -40°C. This distance simulate electric insulator distance of heat pipe used for real application of high voltage electric element cooling. For this experiment was used glass heat pipe with working fluid Fluorinert FC 72. The choice of this fluid is mainly due its excellent dielectric properties and unique combination of the thermodynamic and others properties, which makes the Fluorinert FC - 72 ideal fluid for electronic cooling used in many electronic applications.*

Keywords: HEAT TRANSFER, ELECTRICITY, HEAT PIPE, DIELECTRIC BREAKDOWN

1. Introduction

The cooling problems solution are currently still difficult, especially when in cases of cooling the electrical and electronic equipment, because their size are still reducing, performance characteristics are still increasing so this create still more demanding requirements to cooling them and therefore are new types of the cooling possibility in electronic cooling still developing. The heat pipe technology seems to be a one from the new cooling possibility. The heat pipe technology is mainly used to heat removal from a heat sources where common cooling technologies cannot be used from various reasons (e.g. small space or difficult access) to the places, wherein the waste heat can be dissipated to surrounding. The heat pipes are develop with electronic devices developing and today are known many kinds with various shapes and design considering to the intended use [1].

The basic type of heat pipe is a hermetic sealed pipe with working medium inside (water, alcohol, freon, mercury, ammonia, helium, ethanol, toluene, sodium ...) at a given pressure. It is divided into three parts - evaporation, condensation and adiabatic (isothermal) part. The heat loaded to the evaporation section of the heat pipe causes the working medium in the liquid phase start evaporate due effects of increasing temperature at corresponding pressure. Vapor flows through the adiabatic part into the condensation part, where condenses to a liquid and release latent heat. Then the condensed liquid is returned to the evaporation part by gravity, capillary or centrifugal force, depending on heat pipe type. Thus is created a closed cycle flowing the working fluid in conjunction with the heat transfer. Since the heat pipe is mostly made from one piece of metal material, it becomes the good heat conductor as well as electrical conductor. If the heat pipe is used to heat remove from electric elements plugged to high electric voltage there is in case of electric short danger. If the evaporator is not electrically separated from the rest heat pipe parts by insulated material, the electric voltage can pass through the heat pipe container to the condensation part and this is undesirable in view of safety at work. In addition at heat pipes the electric voltage can pass through the working fluid. Therefore heat pipes used to heat remove from electric elements plugged to high electric voltage has evaporator separated from the rest parts by the insulator and as a working fluid are used dielectric substances. But there is still risk of the dielectric breakdown inside heat pipe container between evaporation and condensation part. This work deal about influence of ambient temperature and insulator length on dielectric breakdown through the vapor phase of working fluid inside heat pipe [2].

2. Working fluids selection

This part deal about selection of the working fluid used for experiment. There are described characteristics of various fluids commonly used in heat pipes for electronic cooling and compared its properties.

Selection of a suitable working fluid depends mainly on the type of application in which is used. In general, there are two cases, if the phase change in the application occur or does not.

Requirements that determine the intended use of the fluids:

1. Thermodynamic properties (density, pressure, specific heat capacity, thermal conductivity, latent heat of evaporation)

2. Physical properties (electrical properties, solubility in water and oils)

3. Chemical properties (flammability and explosiveness, stability, effects on construction materials and oil)

4. Physiological effects on the human body

5. Price

These requirements on substances potentially useful in application of cooling electrical and electronic equipment by heat pipes reduce substance selection to few substances with suitable parameters such as acetone, methanol, ethanol and fluorinert liquids.

Acetone

Acetone (systematically named propanone) is the organic compound with the formula (CH3)2CO. It is a colourless, volatile, flammable liquid, and is the simplest ketone. Acetone is miscible with water and serves as an important solvent in its own right, typically for cleaning purposes in the laboratory. It is a common building block in organic chemistry. Familiar household uses of acetone are as the active ingredient in nail polish remover and as paint thinner.

Acetone is produced directly or indirectly from propylene. Approximately 83% of acetone is produced via the cumene process as a result, acetone production is tied to phenol production. In the cumene process, benzene is alkylated with propylene to produce cumene, which is oxidized by air to produce phenol and acetone.

Acetone is a good solvent for many plastics and some synthetic fibers. It is used for thinning polyester resin, cleaning tools used with it, and dissolving two-part epoxies and superglue before they harden. It is used as one of the volatile components of some paints and varnishes. As a heavy-duty degreaser, it is useful in the

preparation of metal prior to painting. It is also useful for high reliability soldering applications to remove rosin flux after soldering is complete; this helps to prevent the rusty bolt effect. Acetone is used as a solvent by the pharmaceutical industry and as a denaturant in denatured alcohol. Acetone is also present as an excipient in some pharmaceutical drugs [3].

Methanol

Methanol, also known as methyl alcohol among others, is a chemical with the formula CH3OH (often abbreviated MeOH). Methanol acquired the name "wood alcohol" because it was once produced chiefly as a byproduct of the destructive distillation of wood. Today, industrial methanol is produced in a catalytic process directly from carbon monoxide, carbon dioxide, and hydrogen.

Methanol is the simplest alcohol, being only a methyl group linked to a hydroxyl group. It is a light, volatile, colorless, flammable liquid with a distinctive odor very similar to that of ethanol. At room temperature, it is a polar liquid, and is used as an antifreeze, solvent, fuel, and as a denaturant for ethanol. It is also used for producing biodiesel via transesterification reaction.

Methanol is produced naturally in the anaerobic metabolism of many varieties of bacteria, and is commonly present in small amounts in the environment. As a result, the atmosphere contains a small amount of methanol vapor. But in only a few days, atmospheric methanol is oxidized by sunlight to produce carbon dioxide and water.

Methanol is also found in abundant quantities in star forming regions of space, and is used in astronomy as a marker for such regions. It is detected through its spectral emission lines [4].

Ethanol

Ethanol is a volatile, flammable, colorless liquid with a slight chemical odor. It is used as an antiseptic, a solvent, a fuel, and due to its low freezing point, the active fluid in many alcohol thermometers. The molecule is a simple one, being an ethyl group linked to a hydroxyl group. Its structural formula, CH3CH2OH, is often abbreviated as C2H5OH, C2H6O or EtOH. Ethanol is slightly more refractive than water, having a refractive index of 1.36242 (at λ=589.3 nm and 18.35 °C or 65.03 °F). The triple point for ethanol is 150 K at a pressure of 4.3 × 10−4 Pa. It burns with a smokeless blue flame that is not always visible in normal light.

Ethanol is produced both as a petrochemical, through the hydration of ethylene and, via biological processes, by fermenting sugars with yeast. Which process is more economical depends on prevailing prices of petroleum and grain feed stocks.

Ethanol is an important industrial ingredient. Ethanol is used extensively as a solvent in the manufacture of varnishes and perfumes; as a preservative for biological specimens; in the preparation of essences and flavorings; in many medicines and drugs; as a disinfectant and in tinctures; and as a fuel and gasoline additive [5].

Fluorinert

Fluorinert is the trademarked brand name for the line of electronics coolant liquids sold commercially by 3M. It is an electrically insulating, stable fluorocarbon-based fluid, which is used in various cooling applications. It is mainly used for cooling electronics. Different molecular formulations are available with a variety of boiling points, allowing it to be used in "single-phase" applications, where it remains a liquid, or for "two-phase" applications, where the liquid boils to remove additional heat by evaporative cooling. An example of one of the compounds 3M uses is FC-72 (perfluorohexane, C6F14). Perfluorohexane is used for low-temperature heat-transfer applications due to its 56 °C (133 °F) boiling point. Another example is FC-75, perfluoro (2-butyl-tetrahydrofurane). There are 3M fluids that can handle up to 215 °C (419 °F), such as FC-70 (perfluorotripentylamine) [6].

Working fluid properties

In the figures 1, 2, 3 and 4 are compared main thermodynamic and physical properties of selected substances.

In the figure 1 are shown latent heat potential working fluids of heat pipe. Latent heat is thermodynamic properties which indicates the amount of heat that the substance is able to accept at the boiling or transmit at the condensation. Higher value means that the substance is able transmit more heat. This substance properties occur only at the phase change [7].

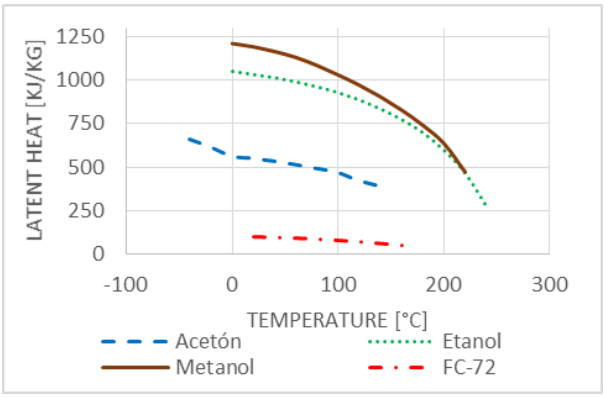

Fig. 1 *Latent heat potential working fluids of heat pipe*

In the figure 2 are shown specific thermal capacity potential working fluids of heat pipe. The specific thermal capacity is thermodynamic properties which indicate the amount of heat, which is necessary add to 1 kg of the substance to increase its temperature by 1 °C. The lower value mean that the substance is able absorb less heat [8].

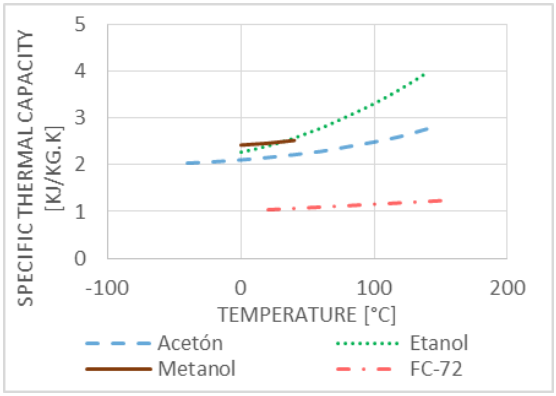

Fig. 2 *Specific thermal capacity potential working fluids of heat pipe*

In the figure 3 are shown boiling points potential working fluids of heat pipe. The boiling point of the substance is the temperature at which the vapour pressure of the liquid equals the pressure of the surrounding atmosphere and phase change from liquid to vapour occur [9].

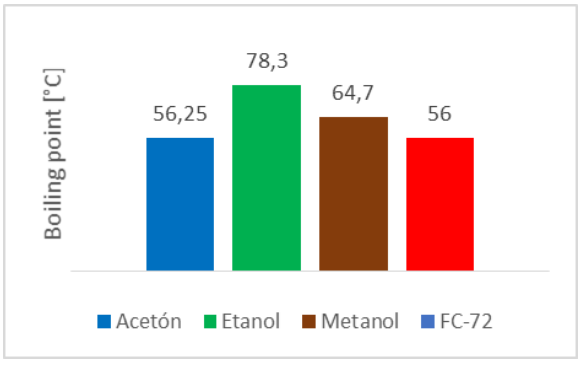

Fig. 3 *Boiling point potential working fluids of heat pipe*

In the figure 4 are shown dielectric constants potential working fluids of heat pipe. This constant indicate the ability of substance to create electrical bonds with other molecules, which means that it is capable eliminate the gravity of opposite charged surrounding ions.

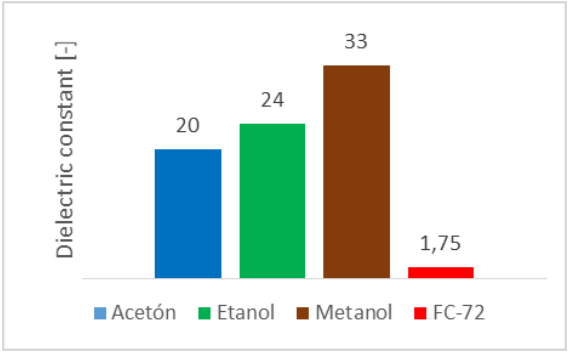

Fig. 4 *Dielectric constant potential working fluid of heat pipe*

3. Experiment

The experiment dielectric breakdown of vapour phase of working fluid in heat pipe was performance on specific designed heat pipe shown in figure 5. It is gravity heat pipe made of a copper pipe, wherein the evaporation and the condensation sections are separated by glass tube of length L, which substitute electrical insulator. According above working fluid selection was the Fluorinert FC 72 choose as a working fluid. The choice of this fluid is mainly due its excellent dielectric properties and unique combination of the thermodynamic and others properties, which makes the Fluorinert FC - 72 ideal fluid for electronic cooling used in many electronic applications.

The experiment investigate influence of ambient temperature and insulator distance on dielectric breakdown of vapour phase of working fluid in heat pipe. There was choose two distances of electric insulator 70 and 65 mm and ambient temperature range from – 40 °C to – 10 °C.

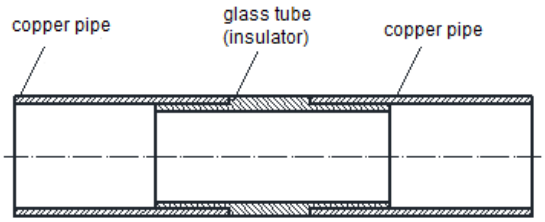

Fig. 5 *Model of gravity heat pipe with electric insulator*

The real experimental heat pipe and dielectric breakdown measurement is shown in figure 6. The measurements were carried out in a thermostatic chamber with temperature regulation. To electric breakdown induction inside heat pipe was evaporator part plugged on the positive pole and condenser part plugged on the negative pole of the laboratory high voltage supply with operating range of 0 to 60 kV.

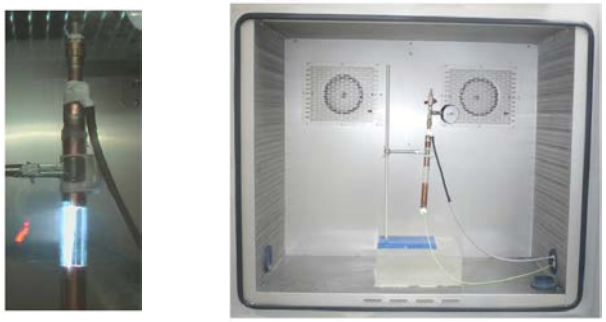

Fig. 6 *Dielectric breakdown measurement*

Than was continuously increasing electric voltage on the laboratory supply till the value when occur dielectric breakdown between evaporator and condenser. Dielectric breakdown was indicated by electric current fail on the laboratory supply and by flash between evaporator and condenser. The same measurement was performance at temperature -40, -30, -20 and -10°C.

4. Results

In the figure 7 are interpreted results of the experiment dielectric breakdown of vapour phase of working fluid in heat pipe depending on ambient temperature and insulator distance. There is seen that with the increasing temperature increase value of electric voltage which inducted the dielectric breakdown at booth insulator distances 75 and 60 mm. Investigation dependence of ambient temperature was limiting by voltage range on the laboratory supply, because the dielectric breakdown inducted by maximal electric voltage 60 kV of the laboratory supply occur already at the temperature – 10 °C.

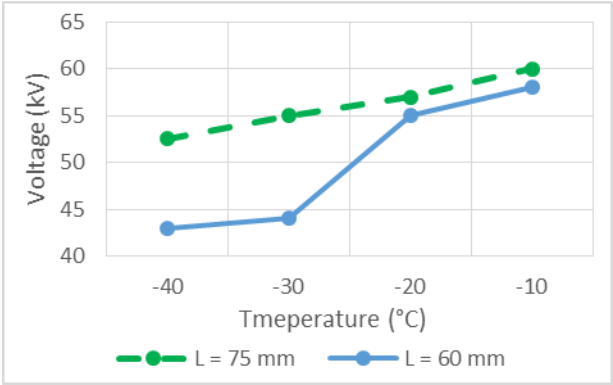

Fig. 7 *Dielectric breakdown of vapor phase of working fluid in heat pipe depending on ambient temperature and insulator distance*

5. Conclusion

Based on the results obtained from the experiment it can be concluded that the heat pipe with electric insulator length approx. 60 - 75 mm and working fluid Fluorinert FC 72 is a suitable device to heat remove from the power electronic components works at high electric voltage and adverse (-40 to -10 °C) ambient temperature conditions.

Acknowledgment

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