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Compare Cooling Effect of Different Working Fluid in Thermosyphon

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Abstract. This work examines cooling effect of various working fluids types, which are used in thermosyphon at cooling electrical component, it's connected to power supply. Measurement is realized at various heat output, which maximal value is limited with maximal operating value of electrical component.

1 Introduction

Loop thermosyphon is a special type of the heat pipe consisting of an evaporator and condenser which are joined with transfer tubes. The evaporator is situated below the condenser. Heat pipes are used as heat transfer. Heat conductivity of heat pipe can be higher than heat conductivity of some metal materials (et. copper). After successful demonstration of the ability and reliability of heat transfer in space applications, the loop thermosyphon experienced the attention of the world in 1990 [1]. Loop thermosyphons are used in the space industry for cooling of electrical equipment on spaceship now, are capable of passive cooling of equipment at normal operation conditions [2]. The phenomenon is often used in the design of solar water heaters, particular of small capacities [3]. Volume of wasted heat depend on the specific heat capacity and boiling point working fluid.

2 Design of loop thermosyphon

The aim of this work is to compare flat condensers and ribbed tubes condenser as part of the loop thermosyphon. The loop thermosyphon consists of evaporator, condenser and transfer tubes. The evaporator is located in the lower part of the loop thermosyphon. It is made of aluminium block and its measures are 155 x 80 x 30 mm (H x W x D). Inside the evaporator there is a tube system of four vertical holes with the diameter of 5 mm, the distance between them is 15 mm. This tube system is connected with two holes with the diameter of 10 mm, which are located on the sides of the evaporator for input and output of working fluid [4]. On the front side of the evaporator semiconductor device is installed. It is connected to a laboratory power supply (of electric voltage and current) and it produces heat. The evaporator and semiconductor device are stuck with heat conductive paste to increase the heat transfer. The temperature of the semiconductor device is controlled by a thermometer to prevent it from the heat failure.

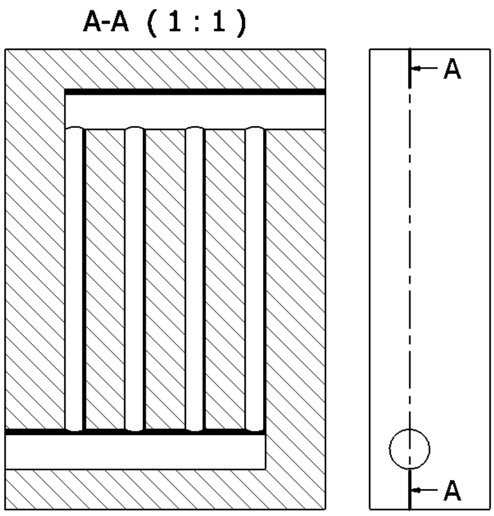

Figure 1 Cross-section of evaporator.

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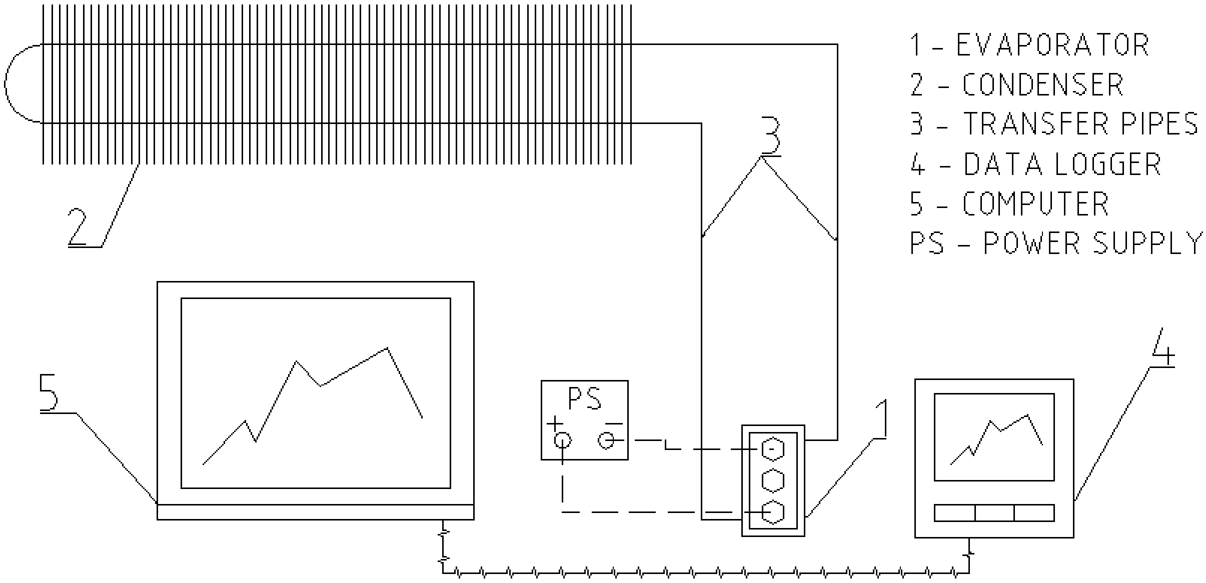

Figure 2 Diagram of devide.

Transfer tubes consist of copper pipes, copper and brass fittings and fastenings which are connected to evaporator and condenser with soft solders and soldering technology. Outside diameter of copper tubes is 10 mm, wall thickness 1 mm. Total length of the transfer tubes, including fittings and fastenings, is 1 m. Capacity of tubes is 50.3 ml. The condenser is located in higher part of the loop thermosyphon. It consist of copper tubes and steel ribs. The ribs are pressed on the tubes. Ribs spacing is 3 mm and rib dimension are 100 x 30x 0.5 mm (H x W x D). Outdoor diameter of copper tube is 15 mm. The condenser is connected via copper tubes to evaporator.

3 Working substance

The working substance used in loop thermosyphon is chosen from the range of liquids depending on their operating temperature. According to operating temperature, the working substances are sorted into four classes: cryogenic (4 – 200 K), low (200 - 550), medium (500 – 750 K), high (750 K and more) operating temperature. The loop thermosyphons are mostly used in applications requiring lower operating temperature. A very important fact at choosing the type of working substance is the compatibility between the working substance and the material of device. It is necessary to avoid every chemical reaction between the working substance and the material of device, because it creates a non-condensable gas in the system [5]. This reaction considerably reduces effect of the loop thermosyphon. We used fluorinert FC-72, acetone, ethyl alcohol and distilled water as a working substance in our investigation. Our choice was based on dielectric properties of this liquid in order not to cause short circuits and damage to the electrical equipment.

3.1 Ethyl alcohol

Pure and denatured alcohol are used in the production of flavour extracts and concentrates for soft drinks and food products, distilled white vinegar, personal care products such as mouthwash, hair sprays, astringents, colognes and perfumes, and a wide range of chemical and pharmaceutical intermediates.

Table 1. Properties of ethylalkohol

Properties	Ethyl alcohol
Chemical formula	C_2H_5OH
Molecular Weight	66
Heating Value (Btu / lb) High Value Low Value	 12.780 11.550
Latent Heat of Vaporization (Btu / lb)	361
Specific Gravity (60 °F)	0.794
Stoichiometric Ratio	9 : 1
Boiling Temperature (°F)	173.3
Octane Number (Research)	106
Energy of Stoichiometric Mixture (Btu / ft^3)	94.7

3.2 Fluorinert FC-72

Fluorinert FC-72 is a clear, colourless, fully-fluorinated liquid. It is thermally and chemically stable, compatible with sensitive materials, non-flammable, practically non-toxic and leaves essentially no residue upon evaporation. This unique combination of properties makes Fluorinert FC-72 ideal for many electronics applications, including quality and reliability testing.

Table 2. Properties of Fluorinert FC-72

Properties	FC-72
Appearance	Clear, colourless
Average Molecular Weight	338
Boiling Point (1 atm)	60 °C
Pour Point	-90 °C
Estimated Critical Temperature	449 K
Estimated Critical Pressure	1.83 x 10^6 pascals
Vapour Pressure	30.9 x 10^3 pascals
Latent Heat of Vaporization (at normal boiling point)	88 J / g
Liquid Density	1680 kg m^{-3}
Kinematic Viscosity	0.38 centistokes
Absolute Viscosity	0.64 centipoise
Liquid Specific Heat	1100 J kg^{-1} C^{-1}
Liquid Thermal Conductivity	0.057 W.m^{-1}.C^{-1}
Coefficient of Expansion	0.00156 $°C^{-1}$
Surface Tension	10 dynes / cm
Refractive Index	1.251
Water Solubility	10 ppmw
Solubility in Water	<5 ppmw
Ozone Depletion Potential	0
Dielectric Strength	38 kV, 0.1" gap
Dielectric Constant	1.75
Electrical Resistivity	1.0 x 10^{15} ohm cm

3.3 Distilled water

Distilled water is a colourless, limpid liquid, without odours or taste, and of neutral reaction. On evaporating one liter of distilled water no fixed residue should remain. The transparency or colour of distilled water should not be affected by hydro sulphuric acid or sulphide of ammonium (absence of metals), by test solutions of chloride of barium (sulphate), nitrate of silver (chloride), oxalate of ammonium (calcium), or mercuric chloride, with or without the subsequent addition of carbonate of potassium (ammonia and ammonium salts). On heating 100 com. of distilled water acidulated with 10 ccm. Of diluted sulphuric acid to boiling, add enough of a dilute solution of permanganate of potassium (1 in 1000) to impart to the liquid a decided rose-red tint; this tint should not be entirely destroyed by boiling for five minutes (absence of organic or other oxidizable matters).

Table 3. Properties of distilled water

Properties	Distilled Water
Chemical formula	H_2O
Molecular Weight	18
Appearance	White solid or almost colourless, transparent with a slight hint of blue, crystalline solid or liquid
Density (1 atm)	999.972
Melting Point	0°C (32 °F, 273.15 K)
Boiling Point	99.98 °C (211.96 °F, 373.13 K)
Thermal Conductivity	0.58 W / m K^{-1}
Refractive index	1.3325
Viscosity	1 cP
Specific heat capacity	75.375 ± 0.05 J / mol K^{-1}

3.4 Acetone

Acetone (systematically named propanone) is the organic compound with the formula $(CH_3)_2CO$. It is a colourless, volatile, flammable liquid, and is the simplest ketone.

Table 4. Properties of Acetone

Properties	Acetone
Chemical Formula	CH_3COCH_3
Appearance	Clear water white liquid
Physical State	Liquid
Molecular Weight	58.08
Density at 20 °C, 68 °F	6.63 lb / US gal
Dielectric Constant 25 °C	21.45
Specific Gravity (25 °C/25 °F)	Not over 0.7880
Vapour Density (Air=1.0)	2
Vapour Pressure at 20 °C, 68 °F	181.7 mmHg (3.51 psi)
Viscosity at 15 °C, 59 °F	0.3371 cP
Water Solubility (miscibility)	Soluble in all proportions in water
Threshold Limit (toxicity)	1000 ppm
Explosive Limits (by volume air)	Lower: 2.6 %, Upper: 12.8 %
Auto ignition Temperature	560 °C (1040 °F)
Boiling Point (760 mm)	56.1 °C (133 °F)
Melting Point (freezing point)	-93.9 °C (-137 °F)
Colour	Colourless

4 Experiment and results

At the beginning of the experiment we have to arrange that the loop thermosyphon contains only pure working substance without air.The purity is the first step to achieve the successful results. Then the data logger is turned on to follow and record heat load and temperature of evaporator, condenser. The power source is set at 80 W of the heat load. The liquid is heated until evaporator temperature become stable. Then the heat load is gradually increased by 20 W. The process of heating continues until evaporator's temperature reaches 100 °C. The percentage of working substance is 50 %.

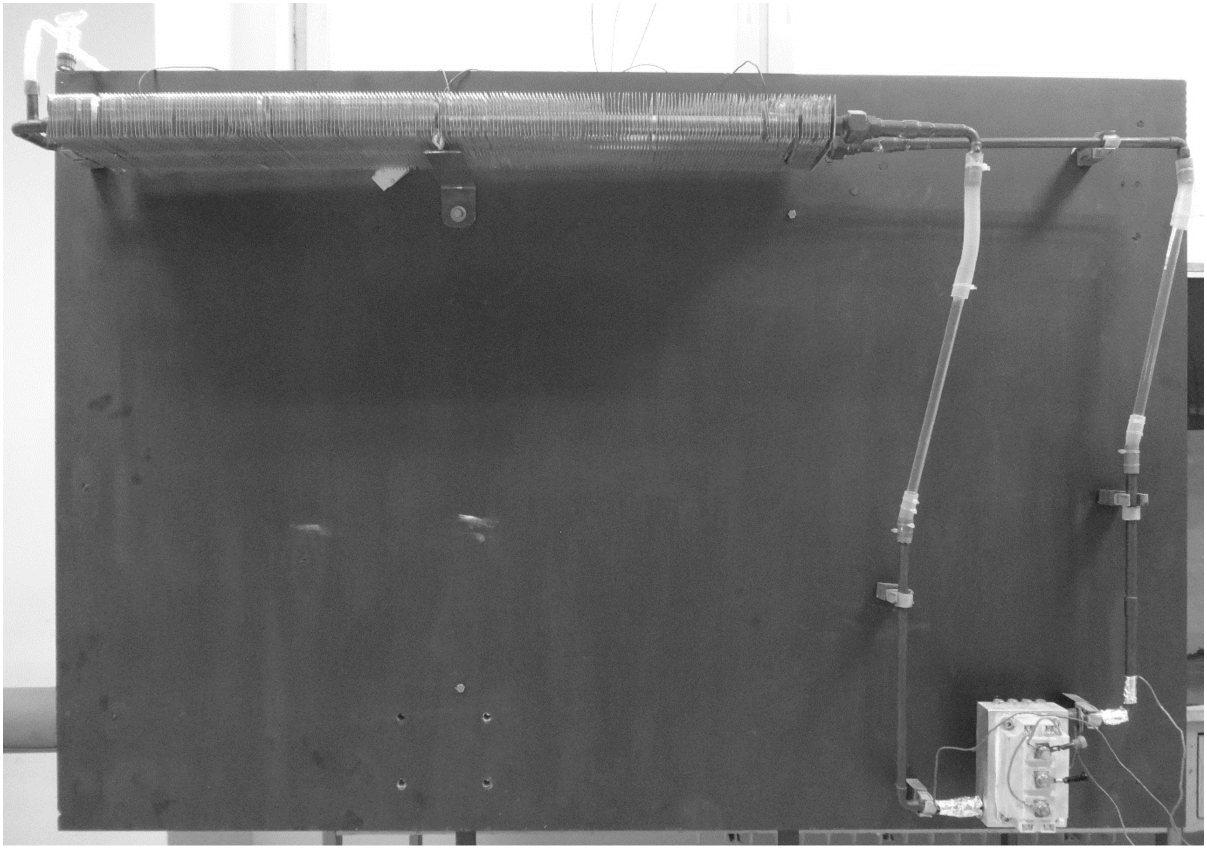

Figure 3 Loop termosyphon at experiment

The measurement data of evaporator´s temperature are showing in table 5. The values are for all of the working substances at corresponded heat load.

Table 5. Value of evaporator´s temperature

Thernal load	Fluorinert FC-72	Distilled Water	Acetone	Ethyl alcohol
80	50.64	74.95	49.28	57.03
100	54.60	78.60	58.31	62.66
120	58.10	79.97	60.85	67.73
140	61.04	81.43	64.33	72.47
160	61.70	82.64	67.76	75.92
180	65.32	83.78	70.07	79.56
200	68.42	84.84	70.73	83.25
220	72.13	87.44	71.52	85.65
240	75.04	89.32	74.57	88.26
260	78.39	90.96	75.76	90.46
280	81.12	92.83	74.73	91.62
300	84.54	94.33	77.74	93.01
320	85.50	95.75	80.53	94.00

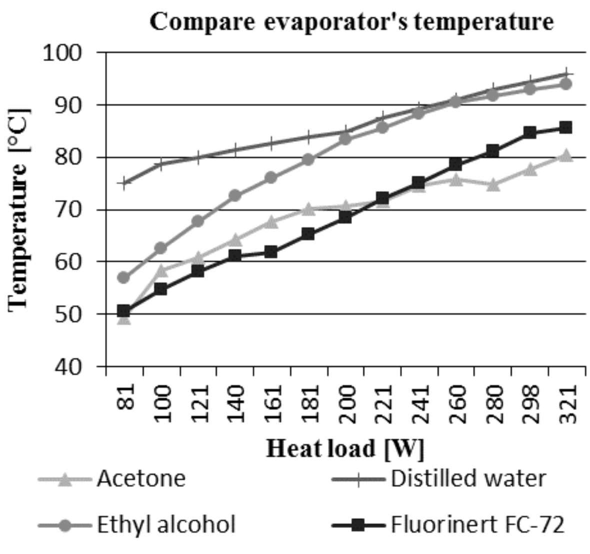

Figure 4. Compare temperatures of evaporator

In the figure 4 is shown depend temperature of heat load.

We can see, that acetone and fluorine achieve the best results of cooling effects as ethyl alcohol and distilled water.

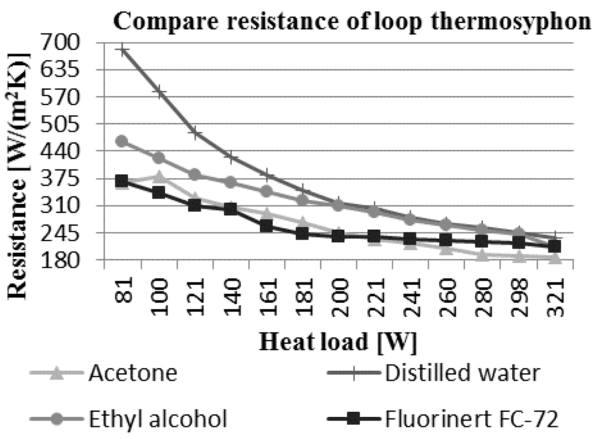

Figure 5. Compare thermal resistance of loop thermosyphon

In the figure 5 is shown depend thermal resistance of heat load. We can see, that with high temperature, which depend on high heat load, is the thermal resistance lower. Acetone achieves the best results of cooling effects as ethyl alcohol distilled water and fluorinert FC-72.

Conclusion

From this experiment is a consequence, that cooling effect depend not only on construction of device, but on working substance too. We don´t known the working substance for ever applications of heat pipe. The used working fluid was comparing for the some experiment. The best cooling effect achieves acetone. Acetone achieve the lowest value of thermal resistance, which is the best for heat transfer to ambient. The next best property is cooling effect of the fluid. Acetone wasted the most capacity of heat from electric element mounted on evaporator. The worst cooling effect achieve distilled water. The cooling effect depend on boiling point and specific heat capacity.

Acknowlegdment

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