Experimental Investigation on Heat Transfer of Non-Contact Liquid Cooling By the Mixture of Water and Propylene Glycol

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Abstract: The electronic components have been ruling the world since few decades. They have made its way into practically every aspect of modern life, from toys and appliances to high speed computers. The number of transistors mounted on a chip gets doubled for every two years. As the number of transistors increase with development of chip integration technology increases the power draw and heat load to dissipate during operation increases. With the development of chip integrated circuits gradual decrease in size of the components has resulted drastic increase in the amount of heat generation per unit volume. Unless they are properly designed and controlled high rates of heat generation result in the failure of electronic component due to high operating temperature.

To dissipate the heat many cooling methods have been developed, but among that liquid cooling has the ability to dissipate more heat from the parts being cooled than the various types of metals used in heat sinks, making it suitable for over clocking and high performance computer applications. Advantages to water cooling include the fact that a system is not limited to cooling one component, but can be set up to cool the central processing unit, graphics processing unit, and/or other components at the same time with the same system.

Among the all working fluids water has an obvious advantage in heat transfer because of its distinctive physical properties. The saturation temperature of water is about 373K. But, the surface of the component is below the saturation temperature of water. So, some substitute medium instead of water was used. An active cooling solution using propylene glycol as a coolant is proposed for electronic components, a series of experiments under different proportions of water and propylene glycol were performed to evaluate the heat dissipation performance of the liquid cooling system and the results were compared with that of water. After conducting the experiments it is decided that the cooling performance of the liquid cooling system is increased by adding propylene glycol to pure water.

***Index Terms* – heat transfer , non contact type , liquid cooling, polyethelene glycol.**

I. INTRODUCTION

1.1 HEAT GENERATION IN ELECTRONIC COMPONENTS:

Whenever a semi conductor is subjected to potential difference there occurs electron hole transition, as a result by virtue of its crystallographic structure it offers a resistance as heat energy for a given semi conductor. The current flow through a resistance is always accompanied by heat generation in the amount of I^2R, where the electric current and R is the resistance. When thousands or even millions of such components are placed in a small volume, the heat generated increases to such high levels that its removal becomes a formidable task and a major concern for the safety and reliability of the electronic devices. The heat fluxes encountered in electronic devices range from 1 w/cm^2 to 100 W/cm^2.

Heat is generated in a resistive element for as long as current continues to flow through it. This creates a heat build-up and subsequent temperature at an around the component. The temperature of the component will continue to rise until the component is destroyed unless heat is transferred away from it. The temperature of the component will remain constant when the rate of heat removal from it is equals to the rate of heat generation.

1.2 COOLING LOAD OF ELECTRONIC COMPONENTS:

Cooling load of electronic components is accompanied by the amount of heat dissipation. The most general way to find out the amount of heat dissipated from the electronic component is to measure the voltage applied and electric current across the component under full load condition and substitute them in relation.

$$W=V.I=I^2R$$

Where, we are the electric power consumption of the electronic devices.

1.3 EXISTING COOLING SYSTEMS:

Present cooling system such as air cooling, liquid cooling .submerged cooling, thermoelectric cooling and heat pipes etc., we are having good enough heat fluxes of 500 to 1000 watt/cm^2, but beyond this heat fluxes the above stated cooling may not be sufficient hence there is need for further research in the field of electronic chip cooling to create superior cooling technologies.

1.4 RECENT TRENDS IN ELECTRONICS COOLING:

In current electronic devices power dissipation increases with each new design. It was already in 1965 that Dr. Gordon Moore, co-founder of Intel, postulated his "Moore's law". His law predicted that semiconductor-transistor-density and their corresponding power outputs roughly double every 18 months. Although Dr. Moore made his predictions in 1965, history seems to validate the 40 years old prediction of Dr. Moore Fig: 1.1.Moore's law is also relevant for power dissipation.

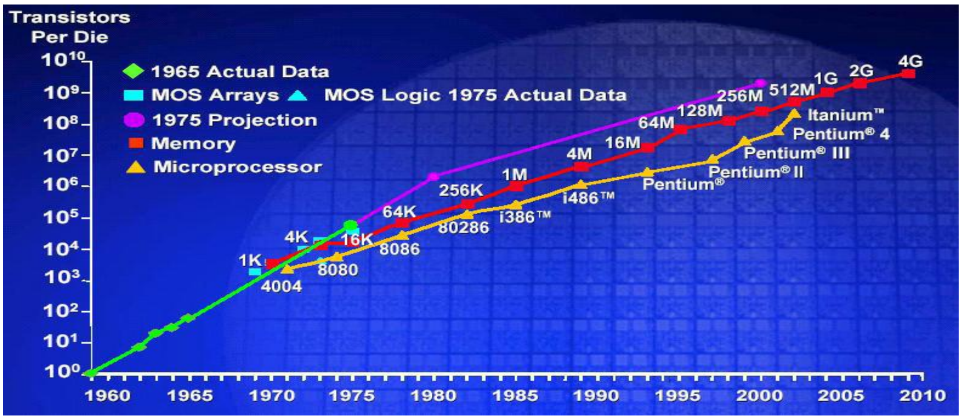


Fig1.1: Number of transistors per die as function of time. This figure validates Moore's assumption of 1965

2. PROPERTIES OF COOLING FLUIDS

At 20^0C:

Type of liquid	Boiling point °C	Freezing point°C	Dynamic viscosity Centi poise	Kinematic viscosity centi stokes	Thermal conductivity $W/m\,K$	Density kg/m^3	Specific heat Cal/g. °C
Water	99.98	0	0.9	0.90	0.609	1000	1
Ethylene glycol	197.6	−12.9	4.9	4.50	0.258	1080	0.87
Propylene glycol	188.2	−59	6.3	6.11	0.34	1030	0.96
Silicone oil	240	-	3.0	3.12	0.15	963	0.4
Synthetic fluids	230	-	2.0	2.60	-	760	0.5
Hydro flouroether	76	−122.5	0.6	0.43	0.068	1430	0.29

Table 1.1 properties of cooling fluids

Among the above liquids, propylene glycol has highest thermal conductivity except water, has high solubility in water and non-toxic among the above liquids. Since water has high thermal conductivity, adding some proportion of propylene glycol to water is preferable.

3. EXPERIMENTAL SETUP

The main objective of our experimental investigation is to compare the effect of cooling with the present technique with that of existing technique on electric components. Cooling of Microprocessor is a hectic task which when not cooled the electronic components may fail to work. In the present work we have conducted experiments by comparing the results with that of existing heat sink and mini-channel water cooling.

The Experimental Setup consists of:

1. Pump
2. Heat exchanger
3. Thermocouples
4. heat sink ,copper tube and copper plate.
5. Mini channels
6. Liquid tank
7. Insulating chamber

3.1 PUMP:

A Centrifugal pump is used to circulate the liquid through mini channels in order to carry away the heat generated by a simulated chip. The pump runs with 12v Dc, 3A. A converter is used to convert AC to DC. The pump used in the experiment is a high speed pump called wiper pump used in Maruhti cars.

Fig 3.1. Electrical Centrifugal Pump

3.2 HEAT EXCHANGER:

It is a radiator used to reject heat absorbed from heat sink. Heat exchanger is fabricated with copper pipes of diameter 1mm. A fan is used to circulate the cool air through heat exchanger

Fig 3.2 heat exchanger

3.3 THERMOCOUPLES:

A thermocouple is a sensor for measuring temperature. It consists of two dissimilar metals, joined together at one end. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature.

Fig 3.3 Digital Thermocouple

3.4 THERMAL INTERFACE MATERIALS:

A Thermal Interface Material (Fig 4.7) is used to fill the gaps between thermal transfer surfaces, such as between microprocessors and heat sinks, in order to increase thermal transfer efficiency. These gaps are normally filled with air which is a very poor conductor.

They take many forms. The most common is the white-colored paste or thermal grease, typically silicone oil filled with aluminum oxide, zinc oxide, or boron nitride. Some brands of thermal interfaces use micronized or pulverized silver.

Another type of TIM are the phase-change materials. These are solid at room temperature but liquefy and behave like grease at operating temperatures. They are easy to handle and are not messy.

Fig 3.4 Thermal interface material

Five factors affect the choice, use, and performance of the interface material used between the processor and the heat sink.

- Thermal conductivity of the material
- Electrical conductivity of the material
- Spreading characteristics of the material

- Long-term stability and reliability of the material
- Ease of application

3.5 THERMAL PROPERTIES:

1. Thermal and interface resistance as function of pressure.
2. Heat capacity and mass density.

3.6 MECHANICAL PROPERTIES:

1. Thermal expansion
2. Moisture diffusion
3. Generally thermal compounds contain chemical composition of ceramic materials like Na_2O, SiO_2, B_2O_3, Al_2O_3 and microscopic sintered materials like Ag, Cu, Au etc.,

Different interface materials used are Elastomer pads, Thermal adhesives, gels, and solders, greases, phase change materials.

3.7 FABRICATION OF SOURCE:

Four Electrical heating coils each of 125W capacity are taken; a copper bar of 2×2 sq.cm with 15cm long is taken (Fig 4.3).The copper bar is fine polished with emery paper; etching agent is also applied to remove the presence of any surface irregularities on the surface of the simulated chip. Finally brazed copper plate acts as microprocessor. To measure the temperature of chip surface a hole is drilled along the sides of the chip.

Fig 3.5 fabrication of copper plate,copper tube, heat sink

3.8 MINI CHANNELS

Mini channels are simply pipes of diameter 1mm to 2 mm. these channels are also called as capillaries in general refrigeration system. These mini channels act as heat sinks. They are properly designed according to the heat dissipation required. In recent past, the focus has changed from macro sized flow channels/pipes to mini/micro counterparts.

This is a natural outcome of the quest for higher transport rates per unit volume of the equipment. While there is no clear demarcation of classification of mini/macro geometrical regimes, according to Kandilkar and Grande, a tentative scheme is as follows

Fig 3.6 copper plates with mini channels

Primarily a support plate for mini channels is cut properly and then the mini channel of diameter 0.5mm are placed parallel at equal spacing so that the required number of mini channels placed over the plate is brazed. A common inlet and exit is made at both ends as shown in Fig 3.6. The number of the mini-channels (tubes) required is 16.

4. COMPLETE ASSEMBLY OF THE EQUIPMENT:

Mini channels of diameter 0.5 mm made of copper are used as heat sinks in this experiment. Heat sink is firmly clamped over the surface of a simulated chip placed over a wooden box for insulation. Thermocouple is brazed to the chip to measure the surface temperature as shown in Fig 4.9

Fig 4.1 complete assembly of equipment

Now the outlet of the heat sink is connected to the heat exchanger inlet where the hot liquid is cooled and the exit of the heat exchanger is connected to the pump which increases the velocity of water hence passing the liquid again into the heat sink forming a closed loop.

Since the atmospheric conditions are varying, the experimentation should be done in closed room for accurate results.

Initially switch on the heater and let the heater to be heated upto the desired working temperature. Meanwhile, prepare the required composition of propylene glycol and water using beaker, measuring cylinder, tunnel, etc. for accurate composition. After reaching the desired temperature of heater switch off it and pour the liquid which is already prepared in liquid tank. Then, start the pumping of liquid through pipe by switching on the electrical pump. Then, measure the time to reach the workpiece temperature to 40℃.

After that note down the readings of thermocouples which are placed at the inlet and outlet of the heat exchanger. Repeat the process for different compositions of propylene glycol and water at different working temperature ranges like 100℃,85℃,80℃, etc. Finally, tabulate the readings and plot the graphs representing the variation of time with the different compositions of propylene glycol and water.

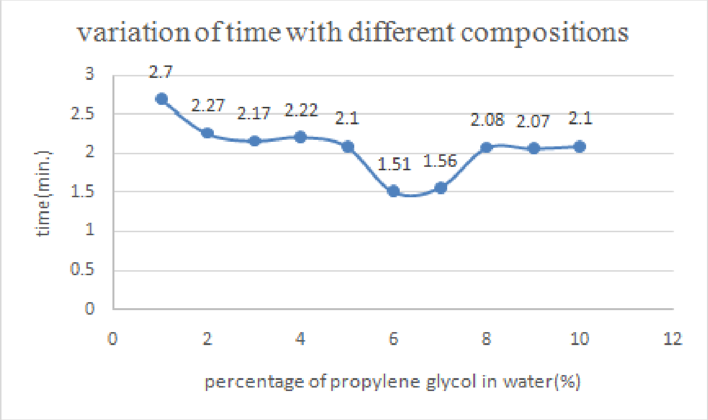
5. EXPERIMENTATION:

A) Initial work piece temperature =100℃

Time taken by the workpiece to reach 40℃ with pure water: 2′07"

Time taken by the workpiece to reach 40℃with pure propylene glycol: 3′10"

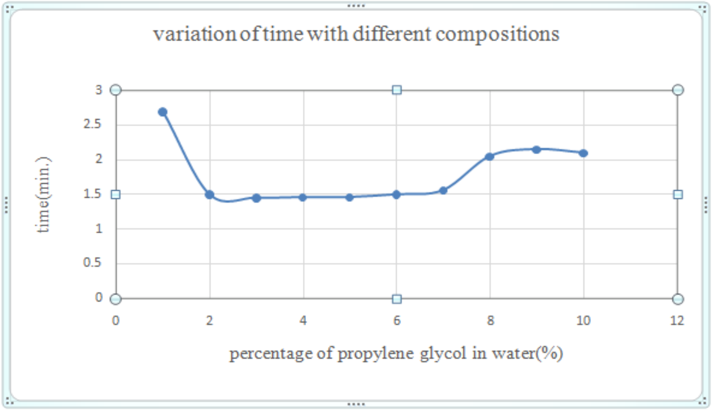
Percentage of propylene glycol mixed with pure water	Time taken by the workpiece to reach 40℃
1	2′07"
2	2′27"
3	2′17"
4	2′22"
5	2′10"
6	1′51"
7	1′56"
8	2′08"
9	2′07"
10	2′10"



B) Initial work piece temperature =85℃

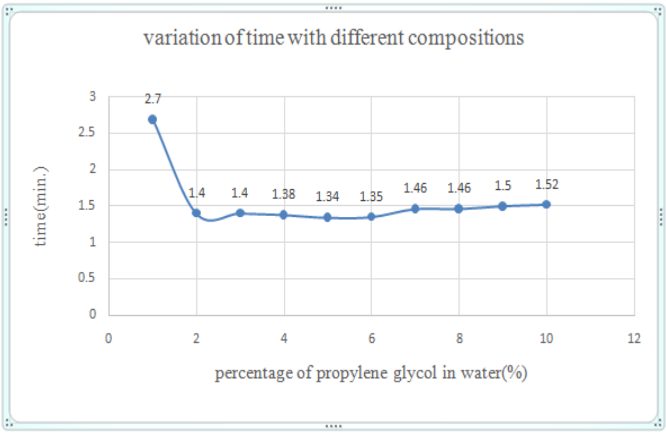
Time taken by the workpiece to reach 40℃ with pure water: 1′52"

Percentage of propylene glycol mixed with pure water	Time taken by the workpiece to reach 40℃
1	2′05"
2	1′50"
3	1′45"
4	1′46"
5	1′46"
6	1′50"
7	1′56"
8	2′05"
9	2′15"
10	2′10"



C) Initial work piece temperature =80℃
Time taken by the workpiece to reach 40℃ with pure water: 1′40"

Percentage of propylene glycol mixed with pure water	Time taken by the work piece to reach 40℃
1	1′37"
2	1′40"
3	1′40"
4	1′38"
5	1′34"
6	1′35"
7	1′46"
8	1′46"
9	1′50"
10	1′52"



Generally, the temperature of electronic components are below 100℃. So, the working temperatures are taken as 100℃,85℃,80℃.
All the above graphs are plotted from the obtained values of time required for cooling at different percentage of mixture of propylene glycol in water with different temperature reductions.

6. CONCLUSION:

A non-contact type liquid cooling system was designed for heat dissipation of electronic components like electronic chips, high power LEDs, IU Servers, etc. Experiments were carried out for different compositions of propylene glycol and water at different temperature ranges. And the results were compared with that of pure water. From the obtained results, it can be concluded that the effective cooling is achieved by adding propylene glycol to the pure water within the range of 3-6%.

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