

## Performance of water and diluted ethylene glycol as coolants for electronic cooling

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### Abstract:

As the number of transistors increases with new generation of microprocessor chips, the power draw and heat load to dissipate during operation increases. As a result of increasing the heat loads and heat fluxes the Conventional cooling technologies such as fan, heat sinks are unable to absorb and heat transfer excess heat dissipated by these new microprocessor. So, new technologies are needed to improve the heat removal capacity. In the present work single phase liquid cooling system with mini channel is analyzed and experimentally investigated. Mini channels are chosen as to provide higher heat transfer co-efficient than conventional channel. Copper pipes of 0.36 mm diameter are taken to fabricate heat sink and heat exchanger. A pump is used to circulate the fluid through heat sink and heat exchanger. A solid heated aluminium block to simulate heat generated electronic component is used and electrical input is supplied to the heated aluminium block and cooling system is placed over the heated block. The performance of the cooling system is analyzed from the experimental data obtained. It is experimentally observed that the mini channel liquid cooling system with water as a coolant has better performance than diluted ethylene glycol as coolant at different flow rates. The surface temperature of the heated aluminium block with convective heat transfer co-efficient is observed

**Keywords:** Liquid cooling, water, diluted ethylene glycol, heat sink, heat transfer coefficient, pump power

### I. INTRODUCTION

Today's electronic components are required to perform tasks at a faster rate, and so high-powered integrated circuits have been produced in order to meet this need. These high-speed circuits are expected to generate heat fluxes that will cause the circuit to exceed its allowable temperature. According to Moore's predictions the number of transistors will get doubled every two years and heat transfer solutions to chip is a continuous research As the number of transistors increase with development of chip integration technology, the power draw and heat load to dissipate during operation increase The failure rate of electronic components increase with increase in temperature. A hot spot created within the electronic components due to low transfer rates seems to be major failure problem. Therefore thermal control has become increasing important in the design and operation of electronic equipments. As a result of high heat loads larger fans and large heat sinks or new techniques are needed to improve the heat removal capacity. The problem with larger heat sinks and fans are objectionable mechanical and thermal stresses and also noise levels. In order to provide greater cooling efficiency many IT systems are currently developing and employing liquid cooling systems

### II. LITERATURE REVIEW

Moore [1] predicted the future of integrated electronics and the advantages of integration. Integrated circuits will lead to such wonders as home computers, automatic controls for automobiles and personal portable communication equipments. The development has been possible only due to integration of millions of transistors, but one of the problems is heat problem. According to his predictions the number of transistors will get doubled every two years and heat transfer solutions to chip is a continuous research. Kanlikar and Grande [2] studied the increased circuit density on today's computer chips is reaching the heat dissipation limits for technology, the direct liquid cooling of chips is being as a viable alternative. He reviewed a liquid cooling with internal flow channels in technological options and challenges. The use of micro channels that incorporate either microstructures in the channels or grooves in the channel surface may lead to significant enhancements in single phase cooling. A simplified and well established fabrication process is described to fabricate both classes of three dimensional micro channels. Wahib Owhaib and Bjorn Palm [3] studied the heat transfer characteristics of single phase forced convection of R - 134a through single circular micro channels with

1.7, 1.2, 0.8 mm as inner diameter were investigated experimentally. Abdulah and Kua [4] experimentally studied the thermal contact resistance to investigate the effect of machined surface roughness at different heat rates. The interface materials have been used in order to reduce thermal contact resistance between two mild steel bars with different surface roughness. It is demonstrated that the use of heat sink compound as an interface material significantly reduce the thermal contact resistance. Gaurav Agarwal, Manojkumar Moharana and sameer kandekar [5] are studied thermo-hydrodynamic performance of hydrodynamically and thermally developing single phase flow in an array of rectangular mini channels has been experimentally investigated. Mohapatra [6] studied the use of a liquid coolant has become attractive due to higher heat transfer co-efficient achieved. Coolants are used in both single phase and two phase applications. A single phase cooling loop consists of a pump, a heat exchanger and a heat sink. The heat source in the electronics system is attached to the heat exchanger. Liquid coolants are also used in two phase system.

Gilles Roy, Nicolas Galanis [7] experimentally investigated the behavior and heat transfer enhancement of a particular nanofluid,  $Al_2O_3$  nanoparticle-water mixture, flowing inside a closed system that is destined for cooling of microprocessors or other electronic components. Uttam Ghosal, Andrew Carl Miner [8] examined that a system to provide effective removal of heat from a high power density device. The system has a heat spreader and a heat sink structure. Electromagnetic pumps are placed inside each chamber easy circulation of liquid metal inside the chamber. The liquid metal preferably is an alloy of gallium and indium that has high electrical conductivity and high thermal conductivity. The liquid metal carries heat from a localized area and distributes it over the entire spreader. Hans Baumgartner, Anna Vaskuri [9] described a temperature controller that can be used to stabilize and control the p-n junction temperature of high power light emitting diodes (LED) for research purposes. The controller utilizes resistive heating and liquid cooling instead of the traditional thermoelectric element based on Peltier effect. Kenneth and Goodson et al [10] investigated the performance of microchannel cooling system for microprocessor and found that the surface temperatures are below the air cooling techniques. Steinkel and Kanlikar [11] studied the single phase heat transfer enhancement techniques are well established for conventional and compact heat exchangers. In the present paper, the applicability of these techniques for single phase flows in micro channels and mini channels is evaluated. Jiyunzhao Assel Akanova, Shan Yin [12] compared two

advanced micro channel structures, i.e., double-layer and double-layer (sandwich) with water as coolant, are optimized and compared by computational fluid dynamics study. Water based  $Al_2O_3$  nanofluid is further applied which shows remarkable improvement for wide channels. A.J. Robinson, B.P Whelan [13] a liquid CPU cooler has been designed and tested. The primary aim of the design was to develop thermal hardware components that can be manufactured simply and cost effectively. To this end, a miniature jet array waterblock and a tube bundle remote heat exchanger were employed since the bulk of their housings could be manufactured using low cost injection molding techniques which could significantly reduce the total system cost compared with conventional units.

### III. EXPERIMENTAL SET UP

The main components in the experimental set up consists of:

#### III.1 Heat Sink

A copper plate of overall dimension  $38 \times 38 \times 2.5$  mm is cut properly. The copper plate supports the copper tubes of 0.36 and 1 mm inner and outer diameter respectively with a length of 40mm. The numbers of copper tubes are 18. as shown in fig.1. To give common inlet and outlet, copper tubes are inserted into two more copper tubes of inner diameter 5 mm. Outlet of the pump is connected to inlet tube of the heat sink and other end of the heat sink is connected to inlet of the heat exchanger. A K type thermocouple is inserted to outlet of the heat sink for measuring outlet temperature of heat sink.



Figure 1. heat sink

#### III.2 Aluminium Block

An aluminum block of  $38 \times 38 \times 70$  mm with a hole of dia and length 10mm and 40mm respectively was simulated as a heated electronic device. And two thermocouples were attached on the top surface of the block to measure its surface temperature. And the assembly of the block with thermocouples was shown in fig 2



Figure 2. Aluminum block with thermocouples

### III.3 Pump

A centrifugal pump is used to circulate liquid through the mini channels of the heat sink.

### III.4 Heat Exchanger

It is a radiator used to reject heat absorbed from heat sink. Heat exchanger is fabricated with copper pipes of diameter 1mm as shown in fig 3.



Figure 3 Heat Exchanger

### III.5 Thermocouples

K Type thermocouple ( chromel- alumel) was used to measure the temperatures. And a digital temperature indicator was used to read the temperatures sensed by the thermocouples.

### III.6 Thermal Interface Materials

TIM was used to fill the gaps between thermal heat transfer surfaces. A white colored paste or silicon oil filled with aluminum oxide, zinc oxide, or boron nitride was applied between the aluminium block and heat sink to increase thermal transfer efficiency as shown in fig 4.



Figure 4. TIM applied to heat sink

### III.7 High Density Cartridge Heater

A heater (shown in fig 5.) of 150W was used to heat the aluminium block acting as a electronic device. It was inserted into the hole machined in the aluminium block. By using voltmeter and ammeter the voltage and current were m



Figure. 5 High density heater cartridge

### III.8 U tube manometer

A differential U-Tube manometer was used to measure the difference of pressure between the pump and heat sink.

### III.9 Assembled Set-Up

The layout of experimental set up was shown in fig 6. An aluminium block which simulates the heat generated by any electronic equipment is used as the heated block. A hole is precisely machined in the aluminium block to insert the high density cartridge heater of capacity there should not be any air gap between the heater and hole. Copper tubes are brazed on a copper plate to form a heat sink. This heat sink was placed over the block by applying TIM between them. Thermocouples were inserted on the surface of the block and another two were inserted into the inlet and outlet of heat sink pipes respectively. This block was placed in a wooden box filled with glass wool which acts as an insulator. The outlet of the heat sink was connected to the heat exchanger where liquid is cooled by means if water or air circulation.

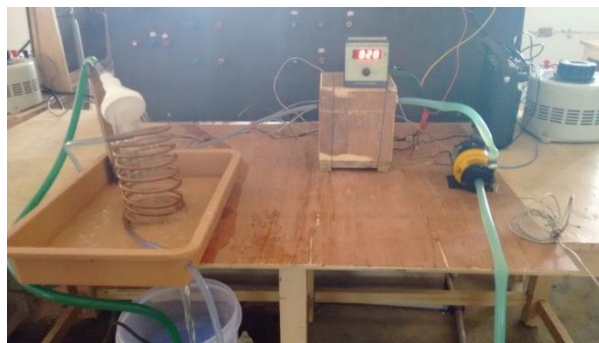


Figure. 6 Experimental Set up

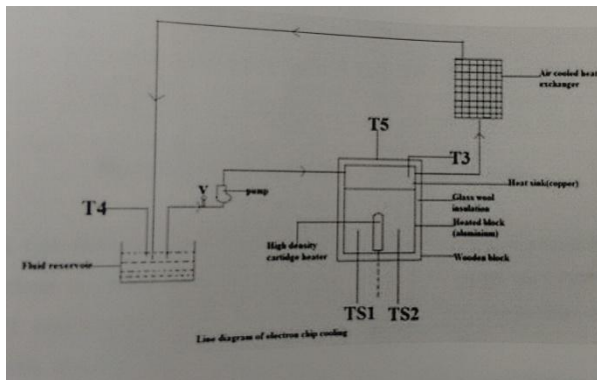


Figure. 7 line diagram of experimental set up

#### IV. PROCEDURE

Initially the setup is tested to ensure that there is no leak in the circuit. For this the setup is run with pure water without giving any heat flux. By using dimmer stat constant heat flux is applied to high density cartridge heater. The voltmeter, ammeter, wattmeter and dimmer stat are used for electrical measurement. The applied heat input is 98 W. Flow rate of water is regulated by using a control valve and the flow rate is measured by using a measuring jar and timer or stop watch. The experiment is conducted for different flow rates starting from 0.3 to 0.65 liters per minute. For each flow rate the inlet and outlet temperature of water, surface temperature of heated aluminium block and surface temperature of wooden box are taken periodically read by using digital temperature indicator. The readings are taken till the system reaches steady state. The pressure difference is taken by using U-tube differential manometer. Ethylene glycol is diluted with water at volume fraction of 40%. The experiment is conducted at different flow rates. For each flow rate the surface temperature of the aluminium block and pressure difference is measured.

#### V. CALCULATIONS

From the energy balance equation the heat loss is calculated. Heat energy carried away by water is given by

$$Q = m_{\text{flow}} c_p \Delta T = m c_p (T_o - T_i) \text{----- (1)}$$

Heat loss is calculated by using

$$Q_{\text{loss}} = Q_{\text{Input}} - Q \text{----- (2)}$$

Mass flow rate,  $m$  of the water is calculated as follows.

Mass flow rate,  $m_{\text{flow}} = \frac{(D \times 10^{-3} \times \rho \times 10^{-3})}{\text{kg/sec}}$ . Velocity of the water through the heat sink is calculated to find out the Reynolds number. 18 numbers of copper tubes are brazed on the copper plate which acts as heat sink. Inner diameter 0.36 mm. So velocity of the water is calculated as follows.

$$\text{Area of the copper tubes, } A = (\pi \times d_i^2) \times n/4$$

$$\text{Discharge, } D = \text{Area} \times \text{Velocity}$$

From the known values of velocity and inner diameter of tubes Reynolds number is calculated.

$$Re = (d_i V \rho) / \mu$$

At mean temperature properties of water such as  $Pr, \mu, \rho$  and  $K$  are taken from data book and Nusselt number is calculated which the function of Reynolds number and prandtl number from the following equation

$$Nu = 1.30 [ (Re \times Pr) / (x/d_i) ]^{0.333}$$

Then convective heat transfer co efficient is calculated from the following equation.

$$h_w = (Nu \times K) / d_i$$

Pump power

$$P = \text{volume flow rate} \times \text{pressure difference} \\ = v \times \Delta p$$

So for different flow rates of water and diluted ethylene glycol convective heat transfer coefficient and pump power were calculated and tabulated. Using these values graphs were plotted between different parameters.

#### VI. RESULTS AND DISCUSSIONS

The surface temperature of the heated aluminium block which simulates the electrical component is the indication of performance of the cooling system. The experiments were conducted with utmost care and readings were tabulated. The values obtained from the experiments with water and diluted ethylene glycol at different flow rates are plotted on graphs and compared with each other. The convection heat transfer co-efficient and pump power is calculated at each flow rate of water and the effect of convection heat transfer co efficient on surface temperature of the heated aluminium block is plotted on graph.

The surface temperature of the aluminium block at different flow rates of water is shown in Fig.7. From the graph the surface temperature of the aluminium block decreases with increase in flow rate. From the graph we can conclude that the surface attain a temperature of 44.8°C when the volume flow rate of water is 0.65 litres per minute. Highest surface temperature is obtained at a flow rate of 0.41 litres per minute. In the present work a temperature reduction of 5.9°C is obtained at 0.65 l/min when compared to the flow rate of 0.41 l/min.

Conventional heat sinks presently used for desktops and laptops cooling are becoming heavier and the noise from the fan is reaching to objectionable level but the minichannel liquid cooling system is quiet in operation and less in weight. Hence the minichannel liquid cooling system is a viable option for future electronics cooling applications.

The effect of volume flow rate on convective heat transfer co-efficient of water is shown in

Fig.8.From the graph we can conclude that the convective heat transfer co-efficient increases with volume flow rate. The convective heat transfer co-efficient increases from 9100W/m<sup>2</sup>K to 10434W/m<sup>2</sup>K when the volume flow rate changes from 0.41 litres per minute to 0.65 litres per minute. As the convective heat transfer co-efficient increases heat transfer rate also increases.The pump power increases from 11.3W to 28.6Wthen volume flow ratechanges from 0.41 litres per minute to 0.65 litres per minute. As the volume flow rate increasespump power also increases as shown in fig.10.

The surface temperature of heated aluminium block when diluted Ethylene glycol at a volume fraction of 40% is used for different flow rates.

From the graph it is clear that the surface temperature increases when ethylene glycol diluted with water is used but the surface temperature is below the optimum temperature of the electronic equipment.

We can conclude that the lowest surface temperature is 41.5°C when the volume flow rate of 40% diluted Ethylene glycol is 0.65 litres per minute. When compared to water the surface temperature of the heated aluminium block is decreased by 3.3°C at this flow rate. The highest surface temperature of 49.6°C is obtained at volume flow rate of 0.41 litres per minute with 40% diluted Ethylene glycol. The convective heat transfer co-efficient with respect to Reynolds number when water is working fluid is shown in Fig.9. As the volume flow rate increases pump power also increases as shown in fig.11. Surface temperature decreases from 49.6°C to 41.5°C when 40% diluted Ethylene glycol is used as working fluid as shown in fig.12.

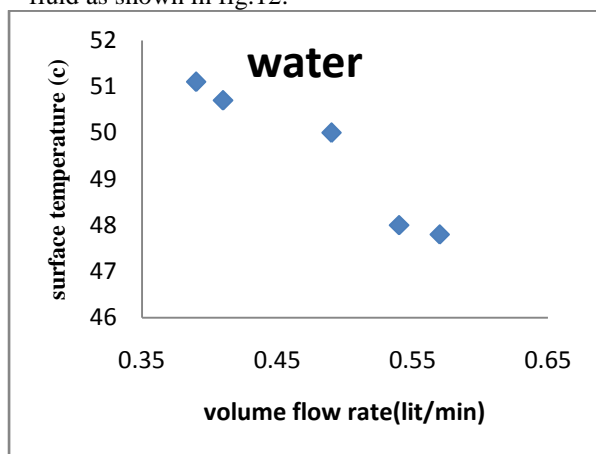


Figure. 7 Effect of volume flow rate of water on surface temperature

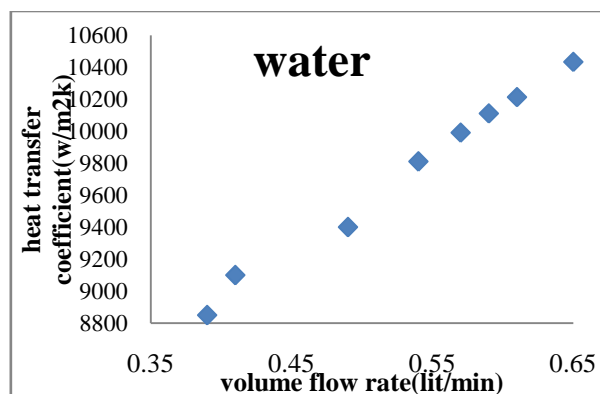


Figure. 8 Effect of volume flow rate of water on convective heat transfer co-efficient

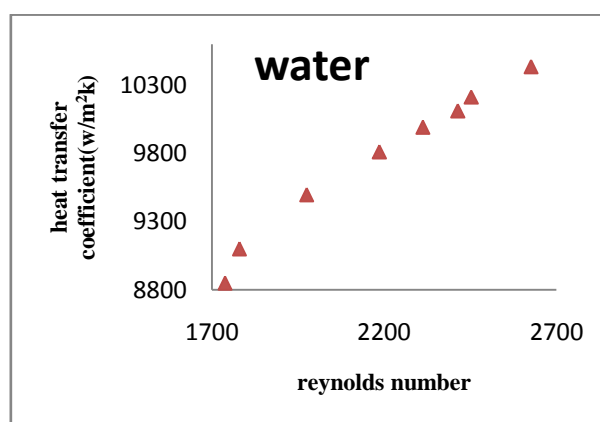


Figure.9 Effect of Reynolds number and convective heat transfer co-efficient

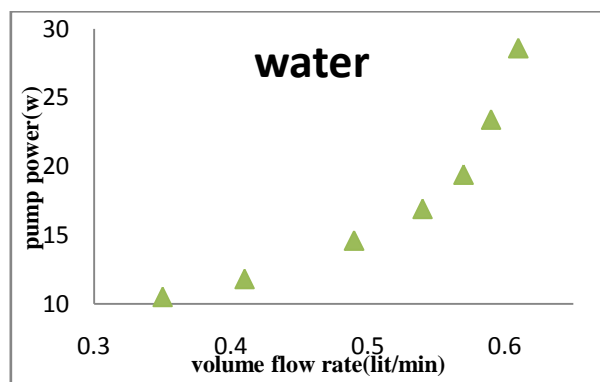


Figure. 10 Effect of volume flow rate of water and pump power

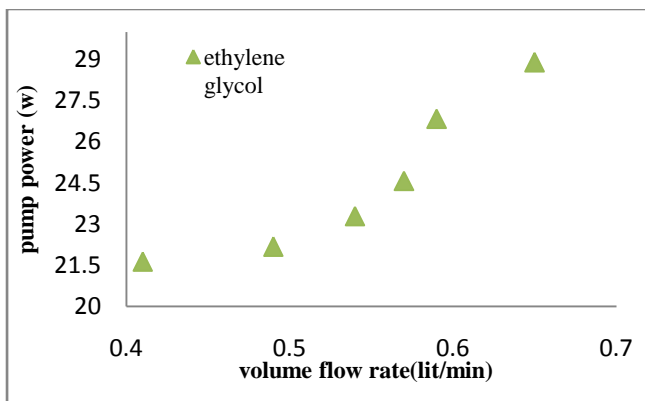


Figure. 11 Effect of volume flow rate of ethylene glycol and pump power

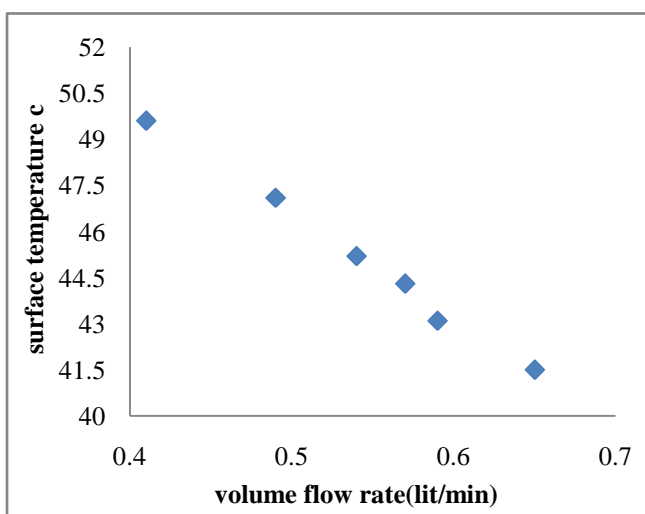


Figure. 12 Effect of volume flow rate of ethylene glycol and surface temperature

## VII. CONCLUSIONS

A mini channel liquid cooling system is designed for cooling of electronic components. Experiments are carried out at various flow rates of water and diluted ethylene glycol, the following are the major conclusions.

1. Heat source surface temperature will go beyond safe limit even for small heat flux, if no heat sink is used.
2. The performance of cooling system is greatly enhanced with application of thermal compounds.
3. When the flow rate is 0.65lit/min and the heat input is 98 W, the surface temperature of heated aluminium block is 44.80c
4. When the flow rate changes from 0.41 to 0.65 litres per minute, 11.6% reduction in surface temperature are observed as 12.73% increase in convective heat transfer coefficient is observed when the flow rate changes from 0.41 to 0.65 litres per minute. There is an increase in surface temperature

when diluted ethylene glycol is used as cooling medium when compared to water.

5. When the flow rate changes from 0.41 to 0.65 liters per minute, 59.4% increase in pump power is absorbed. There is an increase in pump power when diluted ethylene glycol is used as cooling medium when compared to water because the viscosity of diluted ethylene glycol is higher than water.

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