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Experimental investigation of Mini Channel Refrigeration System

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ABSTRACT

The research paper elucidates an investigation regarding the mini channel evaporator which are often used in cooling electronic equipments as well as server station on small scale. For this an actual small scale mini channel heat exchanger was tested using R-134a as refrigerant and a comparison is made between the outgrowth of lose heat and commercially used liquid cooling techniques. Eventually, mini channel's cooling is also compared with air cooling for a conventional heat sink. The result of such analysis demonstrates that the mini channel exchanger is much more proficient in terms of heat transfer rate and cooling effect in comparison with other liquid cooling techniques. The experimental turn-outs also manifest that heat transfer coefficient is more sensitive towards change in refrigerant's mass flux. Overall, it can be said that the mini channel heat exchanger gives quick cooling effect and is much more effective than air cooling systems.

Keywords : R-134a, Electronic Components, Mini/Micro Channel, Miniature-Scale Refrigeration Systems, VCR System

I. INTRODUCTION

From the last few decades there is a continuously demand of scaling down the components for compactness of the devices. To fulfill this demand a group of engineers has a focused goal for the scaling down the components as well as sour their functionality. But by scaling down electronic components or by increasing the number of transistor will result in the increment in value of internal resistance of component. So, according to Joule`s law heat dissipation is given by the equation I2R. Thus, it is obvious that with increasing compactness as well as imparting more amount of resistance, the internal heat generation increases. This internal heat generation has an adverse effect on the working efficiency of the component. Working efficiency decreases with increase in heat generation. So, dissipation of heat flux from the system becomes an indispensable step. This can only be possible by applying efficient cooling medium to the system.

Cooling of electronic components is possible by various medium like liquid, gas, air. Generally, in yesteryears air and water were preferred as most frequently used cooling medium in electronics. If comparison made between the characteristics of air as well as water it is found that, the limit of dissipation of heat by air (as cooling medium) is lesser than that of water which is just about 100 W/cm2. The reason behind this is that, air has less heat carrying capacity than water. Moreover, density of air is also less in comparison to water. Thus, water cooling is far efficient than air cooling to eradicate the heat flux. However, now-a-days instead of water gult of other liquids are used which gives more efficient cooling than that of water.

The introduction of the Mini/Micro channel in the field of the refrigeration and cooling sectors brought a revolution in the aspect of compactness. Mini/Micro channel allows in developing high cooling effect and pressure with less charge of refrigerant at less efforts. Moreover, it can work with all types of refrigerant. With the help of Mini/Micro channel it is possible to compact the size of the components. The concept behind the mini channel is as follows:

$$Q = hA\Delta t \qquad Q \propto h$$

But, $N_U = \frac{hD}{k}$; $h \propto \frac{1}{D}$

Therefore, as $d \downarrow ;\ h \uparrow ;\ Q \uparrow$

So, it is beneficial to have greater hydraulic diameter or in other words more compact design

Miniature-Scale Refrigeration Systems (Msrs) For Electronic Cooling

A schematic diagram of a Miniature-Scale Refrigeration System for electronics cooling is illustrated in Figure 1. The MSRS is composed of six main components: a mini channel evaporator, a compressor, a condenser, expansion devices, as well as a heat source or heat sink, which simulates the CPU. Based on the components indicated in Figure 1, a MSRS was designed and constructed using a commercially available small-scale hermetic reciprocating compressor. The R-134a compressor has a cooling capacity of 1.5 T and pressure ratio: 11 to 25 bars. The mini channel consists of a copper block with dimension of 24.5×30.5×12.5 cm3. A heat sink with a maximum heat dissipation power of 400 W are inserted into the base block that is below the copper block. A variable AC transformer is used to adjust the power input to the heat sink. The evaporator is a microchannel heat exchanger consisting of 23 rectangular channels. Each channel has a cross section having Width (w) - 41.50mm, Length (l) - 84.5mm, Width of slot (a) - 0.350mm, Depth of slot (b) - 3.5mm, Spacing (S) - 1mm. The expansion devices are composed of a capillary tube with 0.7" OD and 0.5" ID. The system was charged with 170g of R-134a. h

The target operating conditions of the MSRS are as follows: cooling capacity of 200 W; mini channel evaporating temperature range from -10 to 6°C; refrigerant at the compressor inlet in the range of 28 to 30 °C; condensing temperature in the range of 40 to 60 °C; and ambient air temperature in the range of 30 to 50 °C.

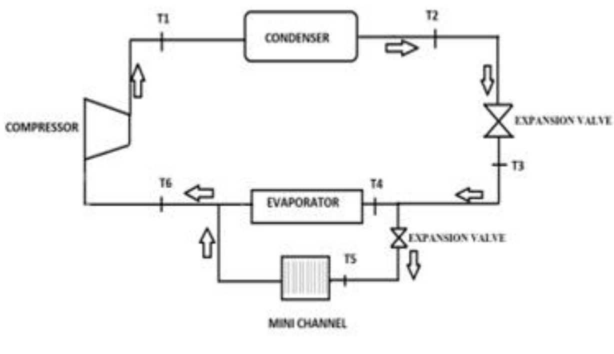


Figure 1. Mini channel copper block. **Figure 2.** Schematic diagram of mini channel refrigeration system.

II. METHODOLOGY

The test is being done to be evaluate the potential of mini channel evaporator as compared to simple evaporator. The performance of the system is identified by analysing the rate of cooling in various conditions. First the test is to be carried out between the MCRS and conventional liquid cooling system in two different cases— Load-based & Time-based. Then another analysis is done between the MCRS and air cooling system.

Here in this experiment support of refrigerator is taken as VCR system to drive the mini channel evaporator. The steady condition of refrigerator and the various parameters observed like higher pressure at compressor, lower pressure at evaporator, condenser inlet-outlet temperature, mini in channel inlet-outlet temperature and load on the compressor. At the ambient temperature the water is placed in the both evaporator at same time. For different quantity and after time interval the load on the compressor, condenser, evaporator, compressor temperature as well as higher and lower observed.

Based on the observation the various performance to be calculated like Refrigerant effect, Work done for specific quantity of water at different time and COP of refrigerator.

The experiments are performed back to back one after another with different quantity to check to the performance of the system. The mini channel is made in copper block is used for this experiment. Condensational channel diameter is greater than 6mm, whereas diameter of mini channel is less than 3mm. Due to this the heat transfer rate in mini channel is very high. Also, it reduces the size of the components in the system, pressure drop occurs in the mini channel due the small size of it. Hence the load on the system increases. Moreover, mini channel evaporator provides quick cooling compared to other evaporators. Hence it has a lot of future potential to be used in electronic as well as data centre cooling.

Moreover, an analysis is made by to justify that the liquid cooling is more efficient as compared to the air cooling. For this once the heat sink is placed on the MCRS evaporator for the dissipation of heat and then the same heat sink is placed in the blow of air by the blower as air cooling technique. Thus, by this we found that liquid cooling is more efficient than air cooling.

The experimental setup consists of five main components. The refrigerant in gases form at low temperature and pressure reaches the compressor, where it is compressed, and the pressure of the refrigerant is increased. Then this high pressure and temperature gas reaches the condenser where the temperature of gas is reduced at constant pressure. Then the high pressure and low temperature refrigerant passes through the capillary tube where its pressure and temperature are further reduced by throttling of refrigerant, forcing it to pass through very small area. Finally, the refrigerant passes through either of the evaporator i.e., conventional and mini channel evaporator with the help of bypass valve. This bypass line is connected to inlet of the mini channel copper block. Both the normal evaporator and mini channel are connected in parallel. The outlet of mini channel is connected to outlet line of the evaporator, which then goes to the compressor for the next cycle.

III. OBSERVATION TABLE

Analysis: 1 water Time: 5 min

Table 1

Quantity (L)	Temperatures of system (°C)								Temperature of water (°C)		
	Compressor		Condenser		Evaporator		Mini Channel		Initial	Mini Channel	Fridge
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet			
0.5	30	66	66	45	10	30	-5.5	10	31	14	26
1.0	31	66	66	45	10	31	-5.5	6	31	16	26
1.5	30	67	67	45	10	30	-5.5	0	31	20	26

Time: 15 min

Table 2

Quantity (L)	Temperatures of system (°C)								Temperature of water (°C)		
	Compressor		Condenser		Evaporator		Mini Channel		Initial	Mini Channel	Fridge
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet			
0.5	30	66	66	45	8	30	-7	10	31	10	22
1.0	31	66	66	45	8	31	-7	6	31	14	24
1.5	30	67	67	45	8	30	-7	0	31	17	23

Time: 30 min

Table 3

Quantity (L)	Temperatures of system (°C)								Temperature of water (°C)		
	Compressor		Condenser		Evaporator		Mini Channel		Initial	Mini Channel	Fridge
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet			
0.5	30	66	66	45	6	30	-9	10	31	4	17
1.0	31	66	66	45	6	31	-9	6	31	11	21
1.5	30	67	67	45	6	30	-9	0	31	14	20

Time: 50min

Table 4

Quantity (L)	Temperatures of system (°C)								Temperature of water (°C)		
	Compressor		Condenser		Evaporator		Mini Channel		Initial	Mini Channel	Fridge
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet			
0.5	30	66	66	45	5	30	-11	10	31	1	13
1.0	31	66	66	45	5	31	-11	6	31	9	18
1.5	30	67	67	45	5	30	-11	0	31	12	18

Analysis: 2 Heat sink/Heater

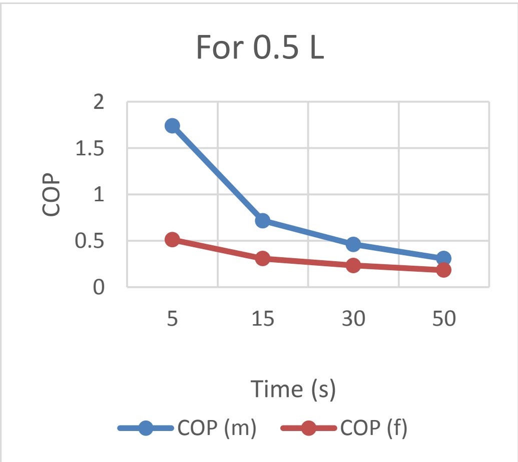
Table 5

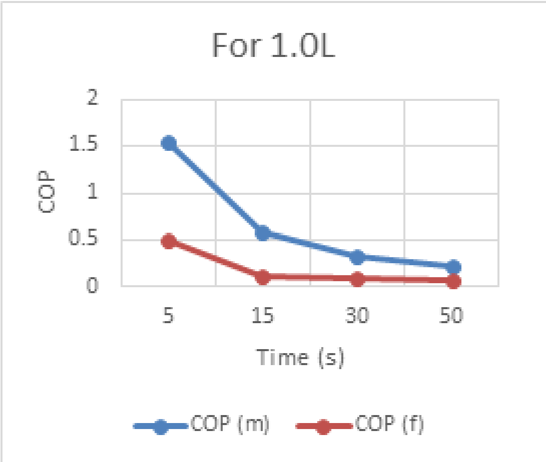
Time (min)	Temperature of heat sink	
	With mini channel cooling(ºC)	With Air cooling(ºC)
0	31	31
10	46	58
20	54	73
30	60	87
40	64	96
50	67	101
60	68	103
70	69	105
80	68	104
90	67	105

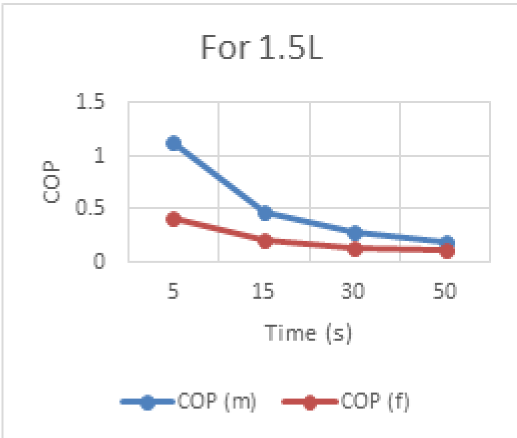
IV. NUMERICAL ANALYSIS

Load based Analysis

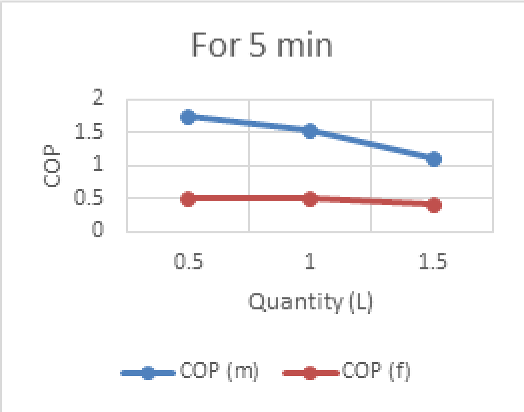
Below graphs shows the comparison of the mini channel and refrigerator. The graphs represent cop vs. time for different quantity of water.

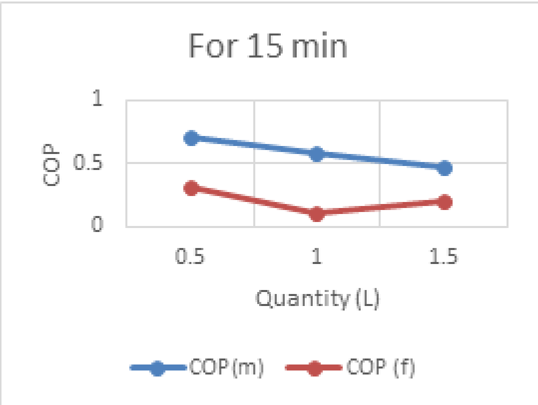


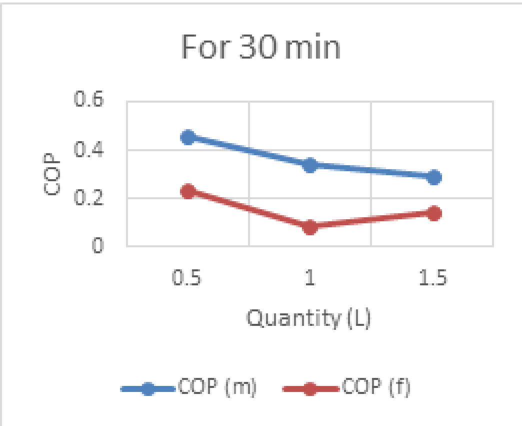


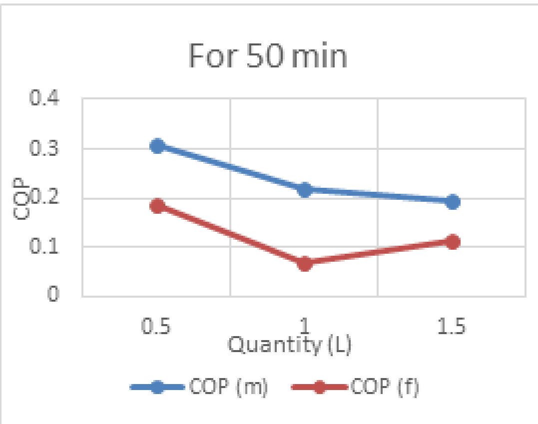


Time base analysis

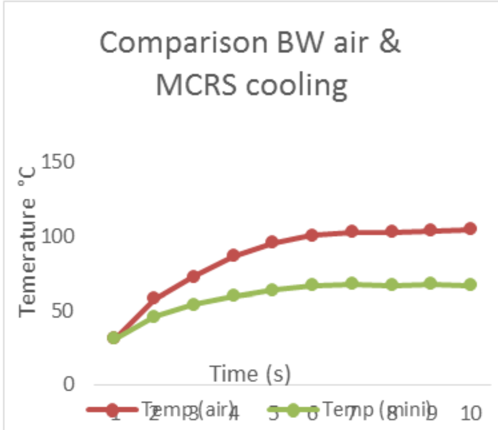








Comparison between air cooling & mini Channel cooling



From the load base analysis, it can be said the performance of the mini channel heat exchanger is always higher than normal evaporator. While from the second analysis which is time based, it can be said the mini channel heat exchanger provides quick cooling than conventional evaporator in any given amount of load on the evaporator. The Graphs above also shows that mini channel provides better and quicker cooling than conventional evaporator on any given load and time. From another analysis it is found that Mini Channel Refrigeration cooling technique is much more efficient than the Air cooling system for the dissipation of heat from the conventional heat sink.

V. CONCLUSION

- ✓ Development and experimental study of a mini channel heat exchanger integrated in a VCR system is based on a refrigerating system was done.
- ✓ Test was carried out to evaluate the potential of mini channel heat exchanger system for electronic cooling (server station cooling). Performance of system is improved by increasing flow of refrigerant in mini channel heat exchanger.
- ✓ When water is placed as load on the system, the mini channel heat exchanger provides efficient

cooling then refrigerator irrespective of quantity of water in the system.

- ✓ The performance of the system is also affected by ambient conditions and the quantity of refrigerant in the system.
- ✓ The refrigerating effect provided by mini channel heat exchanger is always higher than that of the refrigerator irrespective of the load of water on the system.
- ✓ Mini channel heat exchanger provides quicker refrigerating effect than the normal evaporator, for any given quantity of water in the system.
- ✓ The performance of mini channel heat exchanger under a heating load of 150Kw is better than air cooling. It kept the temperature of Dc eliminator below 70ºC while air-cooling increased the temperature of Dc eliminator up to 105ºC then maintained it.
- ✓ The performance of the system is directly affected by mass flow rate of the refrigerant and the pressure drop in the system.
- ✓ The refrigerating effect of the mini channel heat exchanger is higher than the normal evaporator due to the higher heat transfer rate and the COP of 1.75 while conventional evaporates reached the COP of about 0.53.

VI. NOMENCLATURE

- Q= convective heat transfer
- H= convective heat transfer coefficient
- D= Hydraulic diameter
- A= section area
- N_u= Nusselt number
- T_1= Compressor outlet temperature
- T_2= Condenser outlet temperature
- T_3= Temperature after first expansion valve
- T_4= Temperature at evaporator inlet
- T_5= Temperature at mini channel inlet and after second expansion valve
- T_6= Combine outlet temperature of both Evaporator as well as mini channel

VII. REFERENCES

[1]. Giurgiu, O., Pleşa, A., & Socaciu, L. (2015). Plate Heat Exchangers - Flow Analysis through Mini Channels. Energy Procedia, vol. 85(November 2015), pp. 244–251.

[2]. Khovalyg, D. M., & Baranenko, A. V. (2015). Two-phase flow dynamics during boiling of R134a refrigerant in minichannels. Technical Physics, vol. 60(3), pp. 350–358.

[3]. Ghule, K., & Soni, M. S. (2016). Numerical Heat Transfer Analysis of Wavy Micro Channels with Different Cross Sections. Energy Procedia, vol. 109(November 2016), pp. 471–478.

[4]. Raghuraman, D. R. S., Thundil Karuppa Raj, R., Nagarajan, P. K., & Rao, B. V. A. (2016). Influence of aspect ratio on the thermal performance of rectangular shaped micro channel heat sink using CFD code. Alexandria Engineering Journal, vol. 56(1), pp. 43–54.

[5]. Kim, B. (2016). An experimental study on fully developed laminar flow and heat transfer in rectangular microchannels. International Journal of Heat and Fluid Flow, vol. 62, pp. 224–232.

[6]. Hussien, A. A., Abdullah, M. Z., & Al-Nimr, M. A. (2016). Singlephase heat transfer enhancement in micro/minichannels using nanofluids: Theory and applications. Applied Energy, vol. 164, pp. 733–755

[7]. Li, M., Guo, Q., Lv, J., & Li, D. (2017). Research on condensation heat transfer characteristics of R447A, R1234ze, R134a and R32 in multi-port micro-channel tubes. International Journal of Heat and Mass Transfer, vol. 118, pp. 637–650.

[8]. Sahar, A. M., Wissink, J., Mahmoud, M. M., Karayiannis, T. G., & Ashrul Ishak, M. S. (2017). Effect of hydraulic diameter and aspect ratio on single phase flow and heat transfer in a rectangular microchannel. Applied Thermal Engineering, vol. 115, pp. 793–814.