Mini Channel Evaporator as MAC Device for Laptop Cooling System

Elmer Dollera, Jess Kendrick Co, Kristian Jon Dotdot, Jester Lloyd Gamotin, David Jon Mobida

Abstract: ***Laptop computers are known for their compact features which lead to overheating problems. Along with its being compact, laptop computer developers are going for more advance components to be able to run advance computer programs making the laptop do much more which also adds more to the overheating problems of the laptop. Overheated laptops will lead to slower laptop performances, laptop failures and even damaging its components. This problem leads to the development of laptop cooling methods, from fans and blowers and other cooling methods. This study aims to develop a cooling system which involves an air-conditioning system, a Mini Air Conditioning System (MAC System). The key to this study is the fabrication of three(3) mini channel evaporators which has different inner hydraulic diameters but of the same surface area with an overall size and which is smaller than a laptop battery pack. The evaporator for this study was made from a copper block that was fabricated to produce fins and a groove for the refrigerant to flow through the evaporator. The inner hydraulic diameters for the refrigerant to flow through are, 1mm, 2mm, and 3mm. The overall heat transfer coefficient would be determined for each evaporator size. The study showed that the most effective evaporator for cooling the laptop was that of the 3mm evaporator and that using the MAC system is an effective way of cooling a laptop computer. It lowered the temperature of the laptop by 10.65 K versus the setup with no cooler at all and 8.01 K with the setup with a plain cooler. The study also showed that the 3mm evaporator has the highest overall heat transfer coefficient with 73.129W/m^{2}K with a mass flow rate of 0.039 kg/s.***

Keywords: hydraulic diameter, mini air conditioning system (MAC System), mini channel evaporator, overall heat transfer coefficient

Manuscript published on January 30, 2020.

* Correspondence Author

Elmer B. Dollera*, a professor of Xavier University, Cagayan de Oro City, Philippines. Email: edollera@xu.edu.ph

Jess Kendrick Y. Co, a warehouse manager, New Cagayan CCH Hardware, Cagayan de Oro City, Philippines. Email: jesskendrickco@yahoo.com.

Kristian Jon A. Dotdot, a project inspector of Department of Public Works and Highways, Regional Office 10, Cagayan de Oro City, Philippines, Email: jong2_d@yahoo.com

Jester Lloys E. Gamotin, a project engineer of Interglow (S) Pte Ltd. 22 Woodlands Link #03-27, Singapore, Email: gamotinj@gmail.com.

David Jon P. Mobida, a chief engineer, Engineering Department, Ayala Malls - Centrio, Cagayan de Oro City, Philippines. Email: david.mobida@yahoo.com

I. INTRODUCTION

A laptop computer or netbook is a portable and compact personal computer that can be easily transported and conveniently used. A laptop integrates the usual capabilities of a desktop computer that can support applications and software, has memory storage, a keyboard, and many more. It has been widely used and is considered a counterpart for the usual bulky, space consuming desktop computers which are not mobile unlike the laptop computers. Laptop computers these days are not only limited to personal use that are carried around but it is also used commercially in offices and other establishments as a replacement for desktop computers.

Today, laptop computers are more compact and have much higher capacity; unfortunately with the increase in demand for more compact and higher capacity comes with certain problem. As the microchips and processors become smaller and having greater capacity, the unit tends to generate more heat and poses the possibility of reaching the melting points of the components in the laptop especially the microchips that would eventually lead to the decrease of the life of the laptop as a whole, as quoted from http://www.laptop- overheating. com/: Thus, showing the need to study on laptop cooling.

These days, intense heating of laptops led to continuous researches to find the remedies for this problem. Certain laptop coolers were designed by utilizing the natural flow of air or by manipulating the compressed air and many others; but these designs are being left behind because of the upgrading in the laptop technology. This system presents the challenge to design more ways to cool the laptop. This study will be focused on integrating a MAC system to the laptop cooler.

A MAC system makes use of basic air-conditioning process and components. It is composed of the evaporator, condenser, expansion device, and compressor. The evaporator is an essential part of this study for it is where the cold refrigerant is made to flow through the evaporator coils. The refrigerant would then absorb the heat from hot air being emitted by the laptop which follows a certain thermodynamic principle where energy flows from high to low temperature[1]. Blowers are installed to help in the circulation of the warm air in an enclosed space which is the body or case of the laptop cooler.

The authors design and study a MAC System that utilizes a copper block as an evaporator for the system. The design of the evaporator will be as compact as possible and will be in accordance to the discretion of the authors and would be compact as possible with lesser area compared to the common sizes of laptop batteries.

The key to the evaporator design is the determination of the needed mass flow rate of the refrigerant for the design and by using flow meter to measure the flow rate of the refrigerant. A fabricated experimental rig will be used to measure the different thermodynamic properties in order to calculate and compare the overall heat transfer coefficient of the different hydraulic diameters of the inner tubes of the evaporator. The size of computer nowadays are getting smaller and smaller for the sake of portability. Another trend in computer technology is that computer enhancements become so fast bringing high performance capacities for large software and programs.

Combining these, the computer's high capacity and its portability, coupled with fast enhancements causes heating problems. One of the problems that this study aims to solve is the problem about the heat dissipated by the unit. Common causes of excessive heating of the system are: the specifications of the unit itself, poor cooling system, dust that are having an insulating effect on the unit, heavy applications and software that causes the computer to think or process more, and many others.

This study aims to design three(3) mini-channel evaporators with different inner tubes, compare their over-all heat transfer coefficient and determine the required mass flow rate for the certain evaporator design that would be incorporated to the MAC system for the laptop cooler[3].

A. Specific objectives

1. To redesign an existing MAC system by using three(3) mini channels as the evaporator.
2. To measure the mean outlet temperature of a laptop, operating for 60 minutes usage of performing heavy graphic application and operating with and without the cooler MAC system.
3. To determine which diameter for the mini-channel has the higher over-all heat transfer coefficient.
4. To measure the required mass flow rate of the refrigerant for the certain evaporator design.

B. Significance of the study

The study seeks to design a mini-channel evaporator for the improvement of laptop cooling basing on its overall heat transfer coefficient and to measure the actual required mass flow rate of the refrigerant for the designed evaporator.

C. Scope and limitations.

The study concentrates on the design of thre(3) mini-channel evaporators using copper block as the material and the determination of their overall heat transfer coefficient and the required mass flow rate of the refrigerant along the evaporator[4]. The inner tube hydraulic diameters would be 3mm, 2mm, and 1mm.

Only the temperature of the laptop was measured in the study for the study concentrates on the cooling of the laptop. Only a trial version of SiSoftware SANDRA was used during the experiment.

The MAC system would not depend on the size of the whole system as this study will concentrate on the evaporator side, which is the one that is considered to be "mini", because of its hydraulic diameters should be less than 3mm, for it to be considered mini channel[5]. This study will lead to find a more compact evaporator system for laptop cooling requirements. The tools that were used also contributed to the bulky system, specifically the flaring tool that was used which forced the authors to have longer evaporator lines. The inner tube would conformed to a rectangular shape due to the deficiency in milling machine for a required circular tube cut into the copper blocks.

The duration of this study would be limited within nine(9) months. It is limited only in the removal of the heat emitted from the laptop. Other reasons for laptop overheating are neglected, like the presence of dust accumulation from the surrounding and/ or moisture content in the air. The costing of the fabrication of the MAC system also would be limited and would cause the authors to find ways on how to minimize the cost that would be used in fabricating the system[6].

II. METHODOLOGY

A. Research design

Heat energy is a very expensive commodity and waste heat recovery system is very important component in a successful industrial operation for the modern world [7]

The design of the laptop cooler with Mini Air-Conditioning System and the mini channel evaporator were based on two separate studies of previous authors of mechanical engineering students of Xavier University; the studies are: Modified Laptop Cooler Using Mini Air Conditioning System and Coefficient of Heat Transfer of a Mini Condenser[10]. The MAC system was based on the 1st study mentioned and the evaporator design was based on the second study.The flow of the research is shown in the Fig.1:

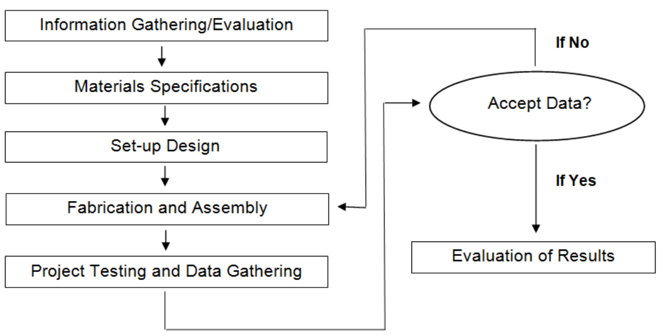

Fig.1. Research flow diagram

B. Materials used

The components for the design in this study are: 1.)water dispenser with its major components; the compressor, condenser, expansion valve and evaporator, 2.)copper tube (1/4 in diameter) for the evaporator line, 3).capillary tube (0.42 in diameter) for the capillary coil, 4.)2 pressure gauges (high side and low side), 5.)Bus Bar/ Copper Block, 6.)Hose clamps, 7.)3mm inner diameter rubber tube, 8.)4 6cm 12V DC exhaust fan, 9.)electrical tape, 8.) ¼ flare knots, 9.) ¼ Tee branches, 10.)90° elbow, 11.)Teflon tape, 12.) O-ring, 13.)Rubber tube insulation, 14.)Silver Tape, 15.)Hand valves (Shut off valve), and 16.)Bolts and knots and 17.)spray paints.

Retrieval Number: E6459018520/2020©BEIESP
DOI:10.35940/ijrte.E6459.018520
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The tools and equipments that will be used in the study are: 1.)oxy-acetylene welding assembly, 2.)surface grinders, 3.)hand drills, 4.) air compressors, 5.) vacuum pumps, 6.) anemometers, 7.) thermocouples, 8.) wrenches, 9.) pliers, 10.) bench vises, 11.) long nose, 12.) hack saws, 13.) flaring tools, 14.) multi-testers, 15.) star and flat screw drivers, 16.) scissors, 17.) hammers, 18.) 3 laptops for the data gathering and 19.) flow meters.

III. EXPERIMENTAL

A. Fabrication of mini-channel evaporator

Three(3) mini channel evaporators, with different inside hydraulic diameters were fabricated. The hydraulic diameters would be 1mm, 2mm, and 3mm.

The evaporators were made out of a copper block. The inner diameter of the evaporator was made through carving a path along one side of the copper block by the use of a shaper machine. After the diameters were carved, the fins were then formed at the other side of the block. In forming the fins, a shaper machine was used. After the fins and the inner diameters were made, the copper block was cut into half and was joined with the other half on top of the other. The opposing sides of the copper block were then welded using oxy-acetylene welding, together with a copper tube at each ends, where the refrigerant would be able to pass through. Capillary tubes were installed at each evaporator. For the 1mm diameter evaporator, the capillary tube diameter was made smaller by inserting three(3) stainless steel wire with a commercial size of Number Four(4). The installed length of each capillary tube is eight(8) feet long. The length of the capillary tube that was installed was done through trial and error and by installing a long capillary tube and by cutting one (1) foot after the other until the required choke point length was obtained, and the system would work effectively with the designed length of the capillary tube.

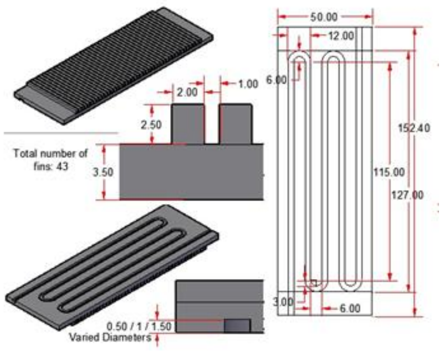

Fig. 2. Fabricated mini-channel evaporator.

B. Assembly of MAC system

A laptop cooler case was made out of transparent plastic, so that the system would be seen from the outside and very much essential for monitoring purposes. The laptop cooler case was made with 100 holes for the air outlet and a certain section was made for the four(4) laptop cooler fans that were installed.

A current water dispenser system was used for the experimental rig and with that, a bypass line was provided for the system[12]. The bypass line was mounted before the refrigerant enters the main water dispenser evaporator, and would then be connected back to the main line after the main evaporator. A hand valve was installed to regulate and distribute the flow of the refrigerant to the main line and the bypass line. The bypass line would lead the refrigerant to pass through the mini channel evaporator. The bypass line was made of ¼" copper tubes that were flared and were connected with flare knots, tee branches, and elbows.

Another bypass line was made along the line before entering the mini channel evaporator for the connection of the flow meter. Valves were again installed to change the direction of the refrigerant to go to the line of the flow meter. After the mini channel evaporator, another valve was installed to regulate the flow of the refrigerant. This is to slow down the flow of the refrigerant and lessen the suction effect of the compressor on the refrigerant, thereby, allowing a longer resident time of the refrigerant in the mini channel evaporator and before going back to the main line. After the system was installed to its place, a leak test was conducted regularly to ensure a constant refrigerant flow. The system was vacuumed prior to the charging of the refrigerant. Soap test was used for the leak test of the system.

C. Data gathering for mini channel evaporator

The MAC system was made to run without the fans, and until the temperature of the refrigerant goes down to its stabilizing temperature. The stabilizing temperature was based on its surface temperature; the inlet, outlet and ambient temperatures of the evaporator; mass flow rate of the refrigerant; and the measured inlet and outlet pressures. A data logger is used to record the temperature, pressure and the mass flow rate at an interval of thirty(30) seconds for a duration of sixty(60) minutes[7].

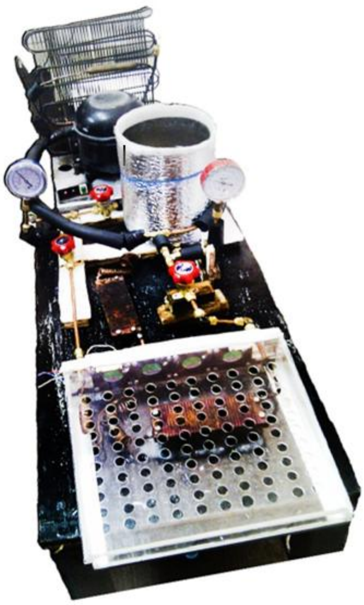

Fig. 3. Experimental rig.

When the system reached its stabilizing temperature, the fans were made to run at a minimal speed so that the warm ambient air temperature would mix thoroughly with the cold temperature of the surface of the evaporator and triggers the reduction of the cooling air.

Same parameters were recorded with the addition of the mass flow rate of the air from the fans and the exhaust air temperature of the cooler. Data were gathered until the system would stabilize the temperature. The stabilizing temperature was then based on the exhaust air temperature of the laptop cooler. The same procedures were applied for all three(3) mini channel evaporators. The data logger recording was made at thirty(30) seconds interval until the stabilized temperature and pressure were obtained[9].

D. Data gathering for the laptop cooling system

A laptop computer was made to run on different trials; without a cooler, with a cooler, and with a cooler that has the MAC system installed with different inner diameters one after the other. The laptop computer was made to run for one(1) hour with thirty(30) seconds interval for data gathering[11].

The Trial Version of SiSoftware Sandra was made to run simultaneously to get the inside temperature of the laptop. Two(2) laptop computers were used for this experiment, each running with a program that has heavy graphic requirements and generates high temperature on the laptop.

IV. RESULT AND DISCUSSION

A prototype system was built for the experiment with the use of a water dispenser system to achieve the specific objectives of the study. A bypass line was made from the main system so that the mass flow rate and the pressure of the refrigerant going in and out of the mini channel evaporator would be controlled. Along the bypass line to the mini channel evaporator, a flow meter was installed to measure the mass flow rate of the refrigerant[13,14]. The system was also made to run with a laptop running a trial version of SiSoftware SANDRA. The results were then obtained through this setup.

1. To redesign an existing MAC system by using 3 mini channels as the evaporator.

Three(3) mini channel evaporators were fabricated with a surface area of 42,029.6 mm^2. The difference between the three(3) mini channel evaporators are their hydraulic diameter which are, 1mm, 2mm, and 3mm. The MAC system is bypassed from a water dispenser system. The mini channel evaporators have their own capillary tube connected to them.

The 1mm evaporator produced a capillary effect due to the small diameter in the evaporator; the copper tubes after the evaporator had lower temperature than the inlet of the evaporator and even the outside surfaces of the evaporator. The temperature of the outside surfaces of the evaporator won't go lower than the freezing point of water at 0°C. This led the authors to insert stainless wire at the capillary tube located just before the evaporator. The authors inserted three(3) Number 4 sized stainless steel wire so that the hydraulic diameter of the capillary tubes will be much lesser than the inner diameter of the fabricated evaporator. With this, the capillary effect of the 1mm evaporator is prevented.

The 2mm evaporator produced a slight capillary effect and that the inlet's temperature is higher than the outlet, but the surface temperature of the evaporator would go lower than the freezing point of water at 0°C. The 3mm evaporator worked as an evaporator should work, with its inlet temperature lower than the outlet temperature.

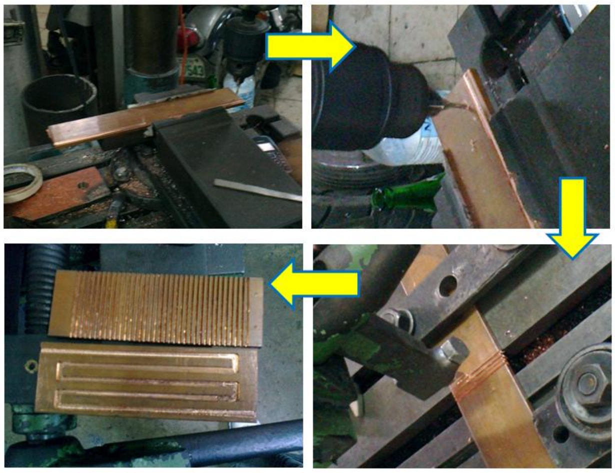

Fig. 4. Fabricated mini-channel evaporator.

2. To measure the mean outlet temperature of a laptop, operating for sixty(60) minutes usage of performing heavy graphic application and operating with and without the cooler MAC system.

The laptop computer that was used was an ASUS laptop with a core i3 processor, 4 GB DDR3 RAM, and a 1 GB ATI Mobile Radeon Video Card. The laptop was tested without any cooler, with cooler, and with cooler with the MAC system.

	Temperature	
System	Board °C	CPU °C
No Cooler	66.75	81.37
With Cooler	65.69	78.73
MAC 1mm	57.95	73.48
MAC 2mm	58.36	72.37
MAC 3mm	58.36	70.72

Fig. 5. Difference in outlet temperature.

The ASUS laptop was first tested without any cooler for sixty(60) minutes, with plain cooler for another sixty(60) minutes, and with MAC system for another sixty(60) minutes for each of the different hydraulic diameter evaporator. A data logger is used to record the data at an interval of thirty(30) seconds and for a duration of sixty(60) minutes[8]. Before testing the laptop, the laptop was placed in a normal state, so that after each trial, the laptop is turned off to normalize the temperature of the system.

The data shows that the mean temperature of the laptop drops from 81.37 °C to 70.72 °C, from no cooler to, with cooler, and then the MAC System with the 1mm, 2mm, and then 3mm evaporator.

The data also shows a drop in the board temperature of the laptop from 66.75 °C to 58.36 °C with the same setup, from no cooler down to with the MAC system with the 3mm evaporator.

Retrieval Number: E6459018520/2020©BEIESP
DOI:10.35940/ijrte.E6459.018520
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The difference in the mean temperature of the laptop cooling system with the installed MAC cooling system is shown in Fig. 6.

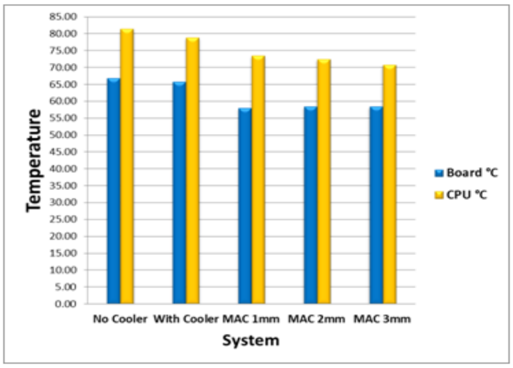

Fig. 6. Difference in temperature with MAC cooling system

3. To determine which diameter of the mini-channel would have the highest overall heat transfer coefficient.

The highest overall heat transfer coefficient among the three(3) mini channel evaporators is the 3mm evaporator, and was followed by the 1mm, and then the 2mm evaporator as shown in Fig. 7.

Mini Channel Evaporator	Over-all Heat Transfer Coefficient	
Diameter mm	U	W/m^2 K
1	58.384	
2	54.296	
3	73.129	

Fig. 7. Overall heat transfer coefficient

The overall heat transfer coefficient for the 3mm evaporator is 73.129W/m^{2}K, followed by the 1mm evaporator with 58.384W/m^{2}K, and the 2mm evaporator with 54.296W/m^{2}K. This deviation for the 2mm evaporator might be caused by the difficulty to regulate the refrigerant flow into the MAC device as shown in Fig. 8.

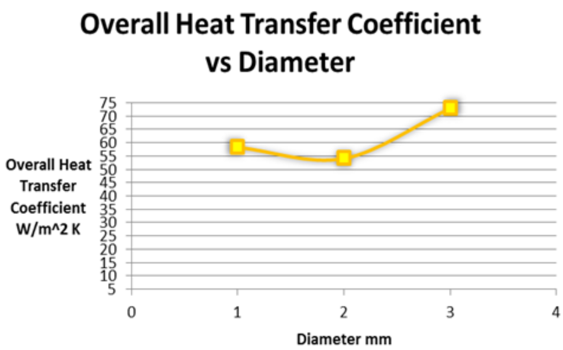

Fig.8. Overall heat transfer coefficient.

4. To measure the required mass flow rate of the refrigerant for the certain evaporator design.

The highest mass flow rate among the three evaporators is the 2mm evaporator, followed by the 3mm, and then the 1mm evaporator.

The 2mm evaporator has a mass flow rate of 0.044 kg/s, followed by the 3mm with 0.039 kg/s, and the 1mm with 0.029 kg/s as shown in Fig. 8.

Diameter mm	Flow rate kg/s
1	0.029
2	0.044
3	0.039

Fig.8. Refrigerant mass flow rate.

The difficulty of controlling the flow of refrigerant in the study of small diameter tubes is not rare.

In this study, the mass flow rate for the 2mm evaporator is high, which obviously triggered by the increased in the overall heat transfer coefficient for the two(2) mm evaporator as shown in Fig. 9.

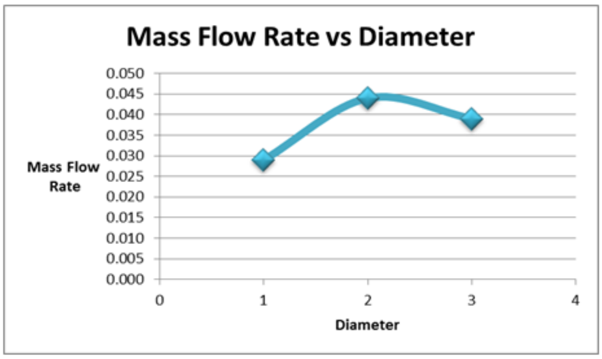

Fig. 9. Refrigerant mass flow rate.

V. CONCLUSION

With the three(3) mini channel evaporators with the same surface area of 42,029.60 mm^2, the results have shown that the 3mm evaporator's performance is better than the other two evaporators, the 2mm and 1mm hydraulic diameters. The 3mm evaporator showed the highest overall heat transfer coefficient with 73.129W/m^{2}K. The 3mm evaporator also showed the best performance with the laptop cooling at a 10.65 K temperature difference compared to the setup with no cooler at all. The 3mm evaporator has a lower cooling temperature difference of 8.01 K compared to a setup with a conventional cooler.

On the mass flow rate analysis, the 3mm evaporator showed the lesser refrigerant mass flow rate compared to the 2mm evaporator but higher mass flow rate compared to the 1mm evaporator with 0.039 kg/s Overall, it can be concluded that in this design, the 3mm mini channel evaporator is the most effective among the other mini channel evaporators for the cooling of laptop computers.

ACKNOWLEDGMENT

The authors of this study are indebted to several personalities, who in one way or another, contributed to the success of the study. The authors would like to express their gratitude to:

Engr. Clark Darwin G. Gozon, Engr. Lester James U. Agum, and Dr. Leonel L. Pabilona, for their invaluable expertise in helping and seeking solutions in the instrumentation system problems.

To our family for supporting us emotionally, and spiritually, during the length of this study.

And most of all, to the Almighty God, who is the source of all the knowledge and all things seen and unseen, who has been with us throughout the duration of this study through the intercession of the blessed Virgin Mary.

REFERENCES

1. R.E.Sonntag, C.Borgnakke and G.J. Van Wylen, "Fundamentals of Thermodynamics", 6th edition, ISBN 978-1-118-13199-2, New York: John Wiley & Sons, Inc., 2013.
2. W. F. Stoker and J. W. Jones, "Refrigeration and Airconditioning," 2nd edition. New York, McGraw Hill, 1982.
3. E.B.Dollera, and E.P. Villanueva, "A study of the Heat Transfer Coefficient of a Mini Channel Evaporator with R-134a as Refrigerant", IOP Conference Series: Materials Science and Engineering. Volume 88 012027, 2014.
4. ASHRAE, :"Handbook of Refrigeration", SI Version, Atlanta, GA, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 1985.
5. E. B. Dollera, E. P.Villanueva, L.L.Pabillona, and R, C. Golez Jr., "Lockhart-Martinelle Correlation of Refrigerant R-134a Pressure Drop in Minichannel Evaporators", Australian Journal for Basic & Applied Sciences, ISSN:1991-8178, Volume-9 Issue-37, Pages 28-34, Special Issue 2015.
6. E.B.Dollera, R.C. Golez Jr., N.G. Ipanag, G.B. Dollera Jr., K. I. D. Liwanag, K. J. A. Dotdot, R.D.Z. Bagayas, and F. E. Joring "Comparative study of pressure drop on a micro expansion device for the development of a mini vaccine carrier", Global Scientific Journals, ISSN: 2320-9186, Volume-7 Issue-8, Pages 613-623, August 2019.
7. J. F. Miraflor, E. B. Dollera, R. C. Golez Jr., N. G. Ipanag, Y. G. Melliza, R. J. A. Cañeda, "An Experimental Study of the Waste Heat Recovery for the Absorption Type Transport Airconditioning System", Global Scientific Journal(GSJ), ISSN: 2320-9186, Volume 7, Issue 9, Pages 177-183, September 2019
8. E. B. Dollera, N. T. Corbita,Jr., M. J. S. Quitiol, J. S. Tagno-ay, J. M. Trazona, "XU Solar Furnace for Recycled Plastic Lumbers," International Journal of Scientific and Technology Research (IJSTR), ISSN:2277-8616(Online), Volume-8 Issue-10, Page No. 877-885, October 2019.
9. E. B. Dollera, R. C. Golez Jr., S. D. R. C. Ty, J. P. F. S. Gaston, J. V. Balo, "Development of XU Plastic Shredder for Cost Effective Means of Minimizing Polyethylene Terephthalate Plastic Waste Volume", International Journal of Innovative Technology and Exploring Engineering(IJITEE), ISSN: 2278-3075, Volume 8, Issue 12, Pages 2821-2825, October 2019.
10. L. L. Pabilona, E. P. Villanueva, and E. B. Dollera, "An Experimental and Simulation Study of Heat Transfer Coefficient of the Mini Channel Condenser for Refrigeration System", Australian Journal for Basic & Applied Sciences, ISSN: 1991-8178, Volume 9 Issue37, Pages 6-14, Special 2015.
11. E.B. Dollera, M. C. F. Rey, A. R. De Jesus, J. M. Piloton, R. R. Salem, Jr., "Water Desalination System using Parabolic Trough with Varying Glass Thickness", International Journal of Engineering and Advanced Technology(IJEAT), ISSN: 2249-8958, Volume 9, Issue 1, Pages 6-11, October 2019.
12. E. B. Dollera, E.P.Villanueva, L. L. Pabilona, K. J. A. Dotdot, G. B. Dollera, Jr., "Temperature Distribution in Mini Channel Heat Exchanger for the development of a Portable Vaccine Carrier," International Journal of Recent Technology and Engineering(IJRTE), ISSN:2277-3878(Online), Volume-8 Issue-4, Page No. 222-226, November 2019.
13. E. B. Dollera, R. C. Golez Jr., J. R. Almedilla, F. B. Libao, F. M. C. Talanda, "Central Processing Unit Binary Cooling System using Tetraflouroethane as Refrigerant", International Journal of Innovative Technology and Exploring Engineering(IJITEE), ISSN: 2278-3075, Vol 9, Issue 2, Pages 1607-1612, December. 2019.
14. E.B.Dollera, C.F.C. Dablo, G.B. Dollera,Jr., H.O. Nasara, K.B.A. Maquiso, "Choke Point in Mini Expansion Device for the Development of Portable Vaccine Kit", International Journal of Engineering and Advanced Technology(IJEAT), ISSN: 2249-8958, Vol 9, Issue 2, Pages 3387-3393, December 2019.

AUTHORS PROFILE

Elmer B. Dollera, is a Professional Mechanical Engineer of the Republic of the Philippines and currently working as a professor in Mechanical Engineering Department, Xavier University, Cagayan de Oro City, Philippines. He earned his degree in Doctor of Engineering in MSU-Iligan Institute of Technology(2015) and Master of Science in Mechanical Engineering(1995) in University of the Philippines, Quezon City, Philippines. He attended a Post Masteral Program in Mechanical Engineering (1997) in University of New South Wales, Sydney, Australia.

Jess Kendrick Y. Co, is a Registered Mechanical Engineer of the Republic of the Philippines He is currently working as a Warehouse Manager of New Cagayan CCH Hardware in Cagayan de Oro City, Philippines. He earned his Bachelor of Science in Mechanical Engineering(2012) in Xavier University - Ateneo de Cagayan, Cagayan de Oro City, Philippines.

Kristian Jon A. Dotdot, is currently working as a project inspector of the Department of Public Works and Highways, Cagayan de Oro City, Philippines. He earned his Bachelor of Science in Civil Engineering(2011) in Xavier University, Cagayan de Oro City and currently working his thesis for the degree in Master of Public Service and Management in Capitol University, Cagayan de Oro City, Philippines.

Jester Lloyd E. Gamotin, is a Registered Mechanical Engineer of the Republic of the Philippines. He is currently working as a Project Engineer of Interglow (S) Pte Ltd, 22 Woodlands Link #03-27, Singapore. He earned his Bachelor of Science in Mechanical Engineering(2012) in Xavier University-Ateneo de Cagayan, Cagayan de Oro City, Philippines.

David Jon P. Mobida, is a Professional Mechanical Engineer of the Republic of the Philippines. He is currently working as Chief Engineer of Ayala Malls - Centrio in Cagayan de Oro City, Philippines. He earned his Bachelor of Science in Mechanical Engineering(2012) in Xavier University - Ateneo de Cagayan, Cagayan de Oro City, Philippines.