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Pressure Drop if Tetraflouroethane in Small Hydraulic Diameter Capillary Tubes

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***Abstract:** Developing a compact device has become a current trend in this modern world which pertains to a lesser energy consumption. It also applies to a mini refrigerator unit to accommodate a small device being cooled wherein the cooling unit has to be in a smaller configuration compared with the conventional sizes. This study focuses on the pressure drop of capillary tubes with six(6) different small hydraulic diameters of 0.20mm, 0.25mm, 0.30mm, 0.35mm, 0.40mm, and 0.45mm with 3 different total lengths of 300mm, 600mm, and 900 mm. Tetraflouroethane liquid refrigerant is used as the cooling medium for the refrigeration system which allows the expansion of the refrigerant in order to absorb heat from the surroundings. In fabricating these six(6) different small hydraulic diameters, stainless steel strings were inserted into the conventional capillary tubes to reduce and attain the required hydraulic diameters. The pressure sensors were installed and pressure readings were then obtained in every 300-mm section of the capillary tube assembly. By allowing the pressurized tetrafluoroethane refrigerant to flow from its reservoir tank through the capillary tubes, pressure readings were taken by the data logger in every 300-mm section of the capillary tube. With these data, the pressure drops were then calculated. Pressure drop of all the six(6) sets of capillary tubes were tested and analyzed. The result showed that the 0.20mm with a length of 900 mm capillary tube has the greatest pressure drop compared to the other specimens of the capillary tubes. It then implies that fabricating a small hydraulic diameter of capillary tube as small as 0.20mm by stainless steel string insertion is possible for 300-mm section, however for the longer section it needs more skills in inserting the string.*

***Keywords:** capillary tube, hydraulic diameter, pressure drop, stainless steel string insertion, tetraflouroethane refrigerant.*

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I. INTRODUCTION

In household and commercial refrigeration system, it is composed of four major parts, namely; compressor, condenser, expansion valve, and evaporator[1].

Each of these devices has a considerable dimension and must be designed proportionally to capacity of air conditioning unit in order for it to meet the cooling load requirement of any enclosed spaces, to which the unit will be installed.

As the booming population of the Philippine archipelago, experiencing progress of an advanced technology and is trying, as much as possible, to bundle many devices and made these devices as compact as possible in its functions and in its applications. One would put an ease to install and insert it into limited spaces without deteriorating its function and applications. This phenomenon is a challenge to every individual engaging into this world of advanced technology. Unfurling back of the application of air conditioning system, it has been used for decreasing temperature of buildings, rooms, containers, and other desirable spaces and as its application is getting smaller in term of volume. The development of new gadgets and other household devices prompted the awareness of engineers to design things in smaller manner and eventually, going for mini and even micro sizes. Refrigeration unit is very essential in household and commercial sector with respect to its unique function and application such as in food preservation, medical storage application and for space cooling operations[2]. This study is focused on how the pressure drop of tetraflouroethane refrigerant behaves in small hydraulic diameter capillary tubes. As an expansion valve of a refrigeration system, the capillary tube is responsible for the reduction of the high pressure tetraflouroethane refrigerant from the compressor to a lower pressure tetraflouroethane refrigerant in the evaporator. This process will significantly reduce the temperature of the evaporator where the heat absorption of the tetraflouroethane refrigerant occurs. Aside from the reduction of pressure and temperature of tetraflouroethane refrigerant, the correct length of the capillary tube must be designed in such a way that the flow of tetraflouroethane refrigerant is made possible even at reduced pressure[3].

As the size of the configuration of the capillary tubes are getting smaller and smaller, fabrication and testing of the pressure drops are more challenging to the authors.

In addition, the degree of work for the design and for measurement of the pressure drop of tetraflouroethane refrigerant at a designated length of the capillary tube becomes harder and more complicated[4].

A. Objectives

1. General objective.
   To gather physical data of fabricated small hydraulic diameter capillary tubes for mini vapor compression refrigeration devices.
2. Specific objectives.

i. To fabricate six(6) small hydraulic diameter capillary tubes, namely; 0.20mm, 0.25mm, 0.30mm, 0.35mm, 0.40mm and 0.45mm

ii. To fabricate a measuring platform and install the six(6) fabricated small hydraulic diameter capillary tubes.

iii. To measure the pressure drops of the fabricated small hydraulic diameter capillary tubes.

iv. To conduct at least 10 test to formulate a statistical correlation between the pressure drops and the length of the small hydraulic diameter capillary tubes.

B. Conceptual framework

The current study will use the maximum conventional pressure drops for capillary tubes, meaning the ideal pressure drop that this study will probably acquire is in the vicinity of 150 psig and which will be the basis of all the process in the study. The length of the capillary tube will also be based on this value. The dimensions and the pressure will be the basis in acquiring the actual pressure drop, and it is needed for a tetraflouroethane refrigerant flowing through this mini capillary tube[5]. Using these data and the projected diagram as shown in Fig. 1, the right model on this study will be plotted down as a guide for the fabrication and assembly of the experimental rig. Certain analysis is then used to check if the actual goal parameters have been met, and if not, the model will be adjusted until it will show the correct parameters.

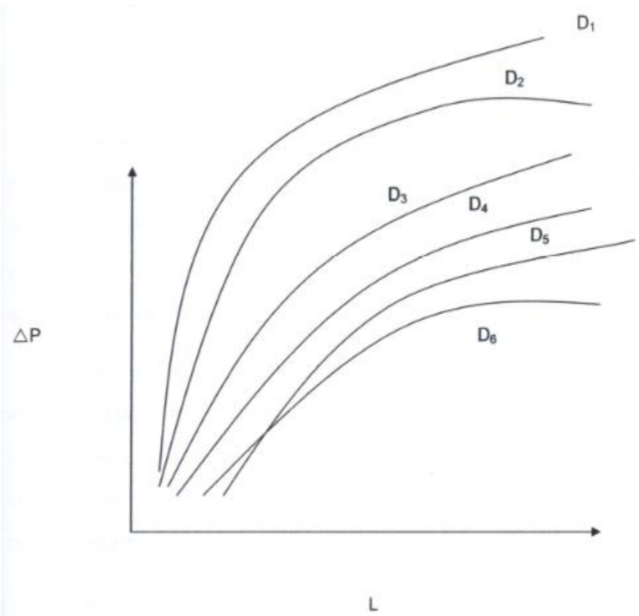

Fig.1. Projected diagram for the pressure drop of tetraflouroethane refrigerant

Other possible characteristics of the tetraflouroethane refrigerant will also be considered such as, the temperature, velocity and other parameters as it will also affect the pressure drop of the refrigerant[6]. The data gathered in this study will then be analyzed to draw a certain observation and the necessary conclusion. As a result, the current study will then provide a driving force for a possible application in designing a mini refrigeration device that can be applied to small electronic devices, especially those gadgets that need cooling systems in order to minimize the accumulated heat and disperse heat faster from such devices[7].

C. Significance of the study

The study is important in the determination of the pressure drops and volumetric flow for small diameter tube that can be used as expansion tube in a mini vapor compression refrigeration system.

D. Scope and limitations

The study covers the measurement of pressure drop and volume flow rate of fabricated tubes. The study is limited only with the available mechanical engineering tools and instruments found in Xavier University Mechanical Engineering Laboratory.

II. METHODOLOGY

A. Research design

The research was started by formulating the research title which is one of four major parts in a single mother unit so called mini refrigeration system. These sections of making the research project are crucial where the research project is introduced, the problem is identified, and the limitations of the research project are set. Related literature and studies will give an account of gathering and formulating data to support the idea presented on this paper.

B. Fabrication

Fabrications of the device subject for experiment will be performed through appropriate manufacturing and mechanical processes importantly applying the workshop practice in order for the device to be tangible with measurable data[8]. Hydraulic diameters of the capillary tubes are set as the independent variable for each trial, and the pressure drop behavior of the tetraflouroethane refrigerant is to be observed. The value of the pressure drop will then be gathered and recorded through series of trials and testing. After the first set of data gathering, data will be presented, interpreted and analyzed to draw a meaningful data presentation. If errors occur in the data gathering and will not satisfy the objectives of this paper, then the authors will then improve the experimental rig and do another set of testing and analysis in order to finally satisfy the objective of this paper. After such, is the formulation of the conclusion and recommendations of the study that are based on the findings and on the results. A tentative schedule of the activities is provided to illustrate the direction of this study[9].

C. Experimental set-up

In the fabrication process, the things that will be fabricated first are the small hydraulic diameter capillary tubes having the initial hydraulic diameter set of 0.20mm, 0.25mm, 0.30mm, 0.35mm, 0.40mm, and 0.45mm. Sleeve tubes will also be included in fabrication, so that there will be a smooth

Transition for the tubes and the joints or the sensor adaptor. T-joints will be fabricated with precision, and it will be considered as the most important part since this will be attached to the access valve where the values of the pressure are being read every thirty(30) seconds for a duration of sixty(60) minutes[10,11].

The small hydraulic diameter capillary tube consists of several parts, namely; T-joints, sleeves, access valves, globe valves and the capillary tube itself which is divided into 300mm apart. This will be inserted with the appropriate stainless strings to reduce its hydraulic diameter. After the capillary tubes are assembled, it will then be attached to the headers and will be attached to the experimental rig.

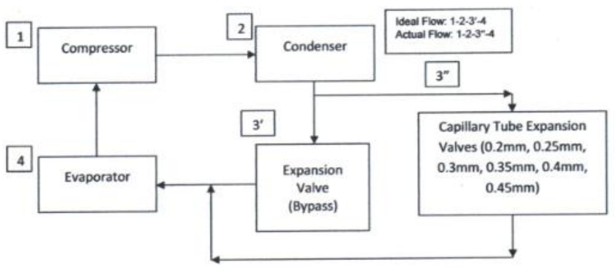

Fig. 2. Flow diagram of the tetraflouroethne refrigerant

The result of the experiment will then be plotted on the above graph, as shown in Fig.1. The graph is represented by the following parameters: the length of the capillary tubes, represented at the x-axis and the pressure drop differences represented in the y-axis. The curve will then be classified with its small hydraulic diameter. As the length of the capillary tube increases, it gives a certain pressure drop in a given hydraulic diameter. This data will then be used to create statistical correlation between the given small hydraulic diameters capillary tube.

D. Testing procedure

The data will be gathered for ten(10) hours, every 60 minutes for every small hydraulic diameter capillary tube and up to ten(10) trials.

The data will be gathered and recorded with the following material needed:

1.4 pcs charging hose

2.4 pcs pressure sensors;

1 high side gage (red), 3 low side gage (blue)

3.4 pcs temperature sensors

The data will then be gathered in conformation with the following testing procedures:

1. Before starting the whole system, make sure that all the globe valves are open and attached to the charging hose on the access valves of the desired small hydraulic diameter capillary tube that will be tested. Make sure that the one that will be attached to the access valve has pin inside its socket.
2. Attach the pressure transducers and temperature sensors on the designated sections of the small hydraulic diameter capillary tube.
3. Attach the pressure transducer to the other end of the charging hose, make sure that all joints are properly tightened, to prevent leaking of tetraflouroethane refrigerant in the system.
4. After all other conditions are checked, start up the system, run the system for 10 minutes or wait for system to stabilize.
5. Then start the first trial run for 60 minutes for the desired small hydraulic diameter capillary tube.
6. After 60 minutes testing run, check the pressure and temperature reading, starting from the high side pressure transducers to the low side pressure transducers. The pressure readings will be recorded as P_1. P_2, P_3, and P_4 respectively.
7. The data will be gathered and recorded every 60-minute interval, up to 10 trials for each small hydraulic diameter capillary tube or the system should be running for about 60 minutes for one specific hydraulic diameter of a capillary tube.
8. Repeat procedures 6 and 7 for the rest of small hydraulic diameter capillary tube. Pressure drop will be then calculated for 300mm, 600mm, and 900mm section of the capillary tube.
9. Take the surface temperatures using temperature sensors for every 30cm section of the capillary tube, the readings will be T_1, T_2, T_3, and T_4 respectively, and this will be at the T-joints of the capillary tubes, starting from the high side. Repeat this procedure for the rest of the small hydraulic diameter capillary tubes.
10. After the 10 trials for the desired small hydraulic diameter capillary tube, turn off the whole system, and wait for the system to stabilize by observing the pressure readings, if the readings will be the same throughout, this means that the system has stabilized.
11. After all the system has stabilized, detach the charging hose from the small hydraulic diameter capillary tube's access valve, and attach it to the next desired small hydraulic diameter capillary tube in the same order. Make sure that the pace in detaching the charging hose is faster so that the refrigerant will not leak at a faster rate.
12. Repeat the whole procedure for the next set of capillary tube diameter.

III. EXPERIMENTAL

The result of the tests made by the authors was exceptional. Comparing to the previous experiment done, it has a very large margin in terms of the pressure readings and the pressure drop. In addition, the data includes surface temperature at every 30cm length of the capillary tube as well as the temperature of the water which is the heat load of the system. The design of the data logger is a crucial part of this study. Proper calibration of the different pressure transducers, flow meter and temperature sensors are made with utmost consideration in order to obtain reliable data from the experimental rig[11].

These data will be recorded in the central processing unit of the assigned personal computer and will be treated as primary data for the presentation and analysis of the results of the experiment[12].

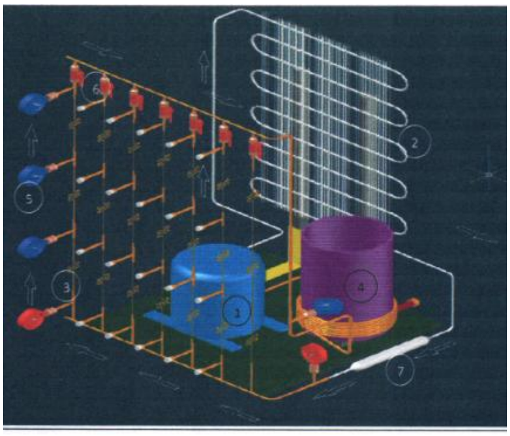

Fig. 3. Experimental rig

The testing consists of six(6) different capillary tubes, classified between 0.20mm, 0.25mm, 0.30mm, 0.35mm, 0.40mm, and 0.45mm, all are at equal lengths at 900mm. The duration of test was sixty(60) minutes for each capillary tube at five(5)-minute interval in ten(10) trials. With the series of data gathered, it is then possible for the authors to do the statistical analysis and create a correlation that would predict a certain pressure drop at any given length and at constant small hydraulic diameters[13].

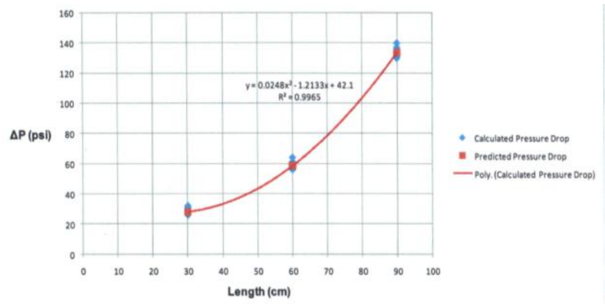

Fig.4. Pressure drop for 0.45mm hydraulic diameter

The data gathered were analyzed using two programs, namely Microsoft Excel 2007 and Minitab Pro v16.1.0; these programs were used for the purpose of having the calculation of the data made easy.

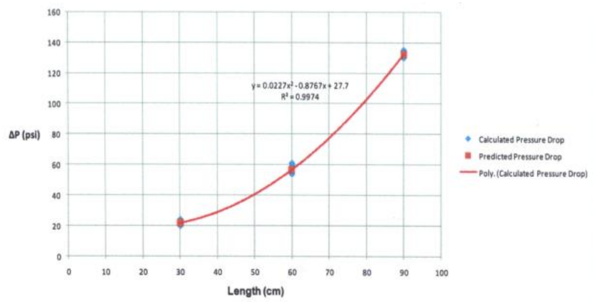

Fig.5. Pressure drop for 0.30mm hydraulic diameter

As a result, the analysis of data was fast and the result was precise and accurate. The following tables were the summary output of the analysis made, using Microsoft Excel 2007.

As a representation of the regression analysis for the other capillary tubes, the summary of the polynomial regression analysis for 0.20mm hydraulic diameter is shown in Table 1. Analysis of variance for the pressure drop in 0.20mm hydraulic diameter is also shown in Table 1 and an approximate representation of the other small hydraulic diameter capillary tubes.

Table 1. Polynomial regression analysis for 0.20mm hydraulic diameter

	df	SS	MS	F	Significance F
Regression	2	53496.8	26748.4	10171.9	1.41834E-39
Residual	27	71	2.63		
Total	29	53567.8			

where:

df = degrees of freedom

SS = sum of squares

MS = mean of squares

F = statistical significance

Significance F = a value which indicates that whether the dependent variable has statistically significant association with the independent variable.

Output Summary of Regression Statistics

Table 2. Regression statistics

Multiple R	**0.99933707**
R2	**0.998674579**
Adjusted R2	**0.998576399**
Standard error	**1.62161328**
Number of observations	**30**

where:

Multiple R= Multiple Correlation Coefficient

R^2 = Coefficient of Determination

Adjusted R^2 = Modification of R^2

Standard Error = standard error of regression

Observations = the number of data gathered in each capillary tube

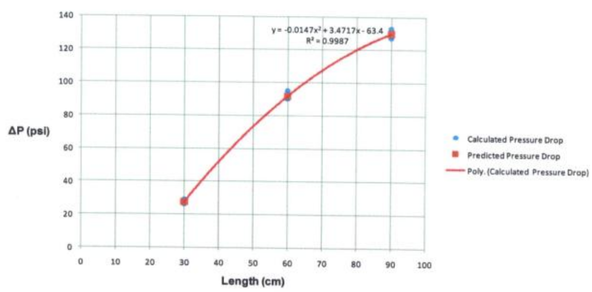

Fig. 6. Pressure drop for 0.20mm hydraulic diameter

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As mentioned earlier, the testing duration is sixty(60) minutes with five(5)-minute interval for each of the small hydraulic diameter capillary tube. But observing the acquired data, it showed a minimal drop of value along each of the ten(10) trials being made. It can be observed that the gathered data on pressure and temperature are significantly accurate and precise, as the pressure drop is closely related with each other. The pressure drop ΔP_1 is low since it is the difference between pressure from P_1 and P_2, P_1 has a pressure reading almost equivalent to the compression pressure of the refrigeration device, while P_2 has a pressure lower than P_1, so the pressure readings from $P_1 – P_4$ is from the highest pressure to the lowest pressure. While ΔP_1 has a low pressure drop, ΔP_2 and ΔP_3 have high pressure drop respectively. This means that as the length of a capillary tube increases, the pressure drop of the refrigeration system is greater relative to their hydraulic diameter. As the hydraulic diameter of the capillary tube decreases, the pressure readings along the tube are relatively low, resulting to the increase in pressure drop[14].

As the tetraflouroethane refrigerant passes through the capillary tube, the readings were constant at about ten(10)-minute test duration but when leaks were observed, the pressure begun to drop. At this moment, the experiment had to be restarted and leaks of tetraflouroethane refrigerant had to be sealed by proper sealing and tightening of the copper adaptor.

The summary output of the regression analysis shows the relationship between the pressure drop, the tube length, and the small hydraulic diameter of the capillary tube. In regression statistics, it is said that the data fits to the regression line if R^2 is equal to one ($R^2 = 1$) and do not fit if R^2 is equal to zero ($R^2 = 0$)[15].

An example of which is at the 0.20mm hydraulic diameter capillary tube, the R^2 value is 0.998 or 99.8%, which is approximately close to 1, this means that the pressure drop along 0.20mm hydraulic diameter capillary tube is best fitted to the regression line plotted in the graph. With a standard error of R^2 at 1.62%, the pressure drop is said to be accurate enough to have the correlation.

The ANOVA analysis or commonly called, the Analysis of Variance, is also one type of statistical analysis that indicates the accuracy and precision of the curve fitting of the correlation. This measures the error of the fitted pressure drop curve between trials, in relation to the predicted pressure drops and the pressure drop values along the regression line. This error or the MSE (mean square error), tells that the probability of having an error in predicting the value of the pressure drop in a given length and at any given small hydraulic diameter capillary tube is most likely equal to the value of MSE. The correlation then can be tested whether the value of pressure drop is statistically significant with the length of the small hydraulic diameter capillary tube by checking the significance F that is less than 0.05 which the standard P-value in the analysis. If the significance F is less than 0.05, we can say that when the length of the small hydraulic diameter capillary tube increases, the pressure drop of the small hydraulic diameter capillary tube also relatively increases.

The residual outputs are the predicted value of pressure drop along the regression line. It is the predicted value of pressure drop (ΔP^1 - ΔP^2) along the regression line. The residuals indicate the error between the pressure drop calculated and the predicted value of pressure drop.

IV. RESULT AND DISCUSSION

The analyses of the pressure drop were done by using two softwares, Microsoft Excel 2007 and Minitab Pro v16.1.0 and these softwares showed and made good results. The summary output showed good results, example of these results are from the 0.20mm small hydraulic diameter capillary tube, the significance F with a value of 1.418 x 10^{-39} which is much less than the P-value standard of 0.05 with a confidence value of 95%, which indicates that the pressure drop is closely related to its length. The confidence value showed the accuracy of the data being analyzed, the remaining 5% showed how the error is being tolerated. So for the six(6) capillary tubes being tested, the authors chose a confidence value of 95% with a tolerable error of 5%, this is the standard value used in many statistical analysis.

The MSE for the 0.20mm hydraulic diameter capillary tube is equal to 2.62%, this means that the correlation between the points in the graph has only 2.62% inaccuracy, this showed that predicting a certain value of pressure drop using this correlation on a given length of 0.20mm capillary tube is 97.38% accurate.

The output of the analysis of the 0.20mm hydraulic diameter capillary tube is shown clearly in the graph, it is observed that the calculated pressure drops (denoted by the blue dots) is closely plotted together along the predicted pressure drop (denoted by the red square). This means that predicting a value of pressure drop along the polynomial regression line (denoted by the curve line along the red square points) at a given length is also 97.38% accurate. This then leads to the correlation equation of $y= -0.0147x^2 + 3.4717x – 63.4$, where:

y = denotes the pressure drop to be predicted

x = the given/desired length of the capillary tube

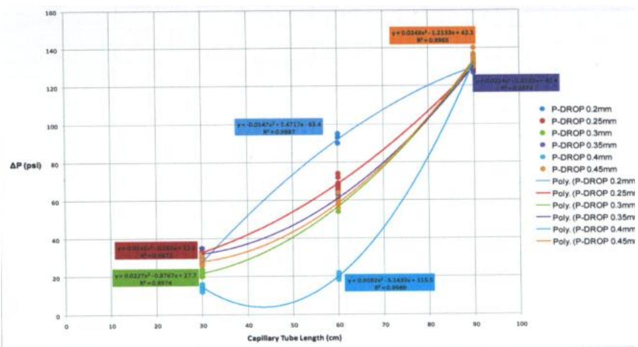

Fig. 7. Pressure drops of various hydraulic diameters

This equation represents the correlation between the pressure drop and the tube length at constant diameter.

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

The overall result of the research shows that the pressure drops of 0.20mm, 0.25mm, 0.30mm, 0.35mm, 0.40mm, and 0.45mm capillary tubes depend highly on both the length and hydraulic diameter of the capillary tubes. In terms of the length of the capillary tube, the pressure drop increases as the length of the capillary tube increases. In terms of diameter, as the hydraulic diameter of the capillary tube decreases the pressure reading will be lowered, resulting to an increase in the pressure drop.

The behavior of the graph in each hydraulic diameter of capillary tube is relatively the same. Comparing the behavior of the graph in Fig.1, the capillary tube with hydraulic diameter of 0.20mm is the only graph that follows the example plot; the other hydraulic diameter of the capillary tubes showed different behavior. This is because of the external constraints present before the testing of the tubes had been made. One of which is the fabrication process involve, during the fabrication process, wherein the difficulty in fabrication was experienced and during the testing which involved the number of strings inserted in the capillary tube to decrease its inner diameter. Among the capillary tubes being tested, the number of strings inserted among them differs greatly; having two of the capillary tubes were inserted with only one string, and the other tubes were inserted with several strings that differ in number. These constraints were the ones involved in changing the behavior of the pressure drop and also the pressure readings in the capillary tube.

These constraints resulted in one special case as observed in the graph with the capillary tube having a hydraulic diameter of 0.40mm and has its ΔP_2 relatively low compared to the other capillary tubes. At one point to another, this behavior is the cause of this unusual curve.

In general, the results in the research show a significant value, the length and the diameter of the tube greatly affect its pressure drop.

Moreover, with the results, the authors find the research applicable towards future development of creating mini refrigeration devices.

B. Recommendations

The proponents encourage those who will conduct the same research as these to;

1. Use longer sleeves in fabricating the capillary tubes as such this will help to decrease the existence of constraints within the tube in order to have a better testing results, precise and accurate data. Good analysis fabrication of a much appropriate T-joint will also lessen the existence of the constraints present. Using the proper valve like the gate valves instead of the globe valves in controlling the flow of the refrigerant within the system will also result to consistent pressure readings.
2. Apply consistency in reducing the hydraulic diameter of the capillary tube, especially in the process of string insertion, which in this case, the number of string inserted and the mode of inserting the strings in the tube is very crucial.
3. Produce more data to be used in the analysis and data presentation. This involves the length of the capillary tube, the hydraulic diameter and the number of pressure of reading sections. Reduce the interval of the sections within the capillary tube, which in this scenario; dividing the total length of the tube into more sections, example of which is, in a 90cm tube, it would be divided by 15cm instead of 30cm sections. Meaning more data will be gathered. Produce more testing trials to have a precise and accuracy in analyzing the data to produce more effective correlation.
4. Include other aspects in refrigeration, namely, the surface temperature in every section, varying the load of the system and the effect of the pressure drop towards the temperature of the load.
5. Enhance the design of the whole system as to which it is possible to isolate a single capillary tube during testing, which in this case, the authors were unable to isolate the capillary tube because it results to a vacuum pressure at evaporator inlet resulting in the starvation of tetraflouroethane refrigerant within the system.

These factors contributing to the design of the capillary tube used as expansion device for the refrigeration device may greatly affect the accuracy of the pressure readings and pressure drop analysis, to even making the obtained values more significant and making the results less deviated from the accurate values.

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REFERENCES

1. Sonntag, R.E., Borgnakke, C. & Van Wylen, G.J.(2013). "*Fundamentals of Thermodynamics*", 6th edition, ISBN 978-1-118-13199-2, New York: John Wiley & Sons, Inc.
2. Stoker, W.F. & Jones, J.W.(1982) "*Refrigeration and Airconditioning*," 2nd edition. New York, McGraw Hill.
3. Dollera, E.B. & Villanueva, E.P. (2014). 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.
4. ASHRAE. (1985).Handbook of Refrigeration, SI Version, Atlanta, GA, *American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc*.
5. Dollera, E.B., Villanueva, E.P., Pabillona, L.L. & Golez Jr., R.C. (2015). 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. Dollera, E.B., Golez Jr., R.C., Ipanag, N.G., Dollera Jr., G.B.,Liwanag, K.I.D., Dotdot, K.J.A., Bagayas, R.D.Z., & Joring, F.E. (2019). 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.
7. Miraflor, J.F., Dollera, E.B., Golez Jr., R.C., Ipanag, N.G., Melliza, Y.G., Cañeda, R.J.A. (2019). An Experimental Study of the Waste Heat Recovery for the Absorption Type Transport Airconditioning System, *Global Scientific Journal*, ISSN: 2320-9186, Volume 7, Issue 9, Pages 177-183.
8. Dollera, E.B., Corbita,Jr., N.T., Quitiol, M.J.S., Tagno-ay, J.S., & Trazona, J.M. (2019). XU Solar Furnace for Recycled Plastic Lumbers, *International Journal of Scientific and Technology Research*, ISSN:2277-8616(Online), Volume-8 Issue-10, Pages 877-885.
9. Dollera, E.B., Golez, Jr., R.C., Ty, S.D.R.C., Gaston, J.P.F.S., & Balo, J.V. (2019). Development of XU Plastic Shredder for Cost Effective Means of Minimizing Polyethylene Terephthalate Plastic Waste Volume, *International Journal of Innovative Technology and Exploring Engineering*, ISSN: 2278-3075, Volume 8, Issue 12, Pages 2821-2825.
10. Pabilona, L.L., Villanueva, E.P., & Dollera, E.B. (2015). 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 Issue 37, Pages 6-14, Special Edition.
11. Dollera, E.B., Rey, M.C.F., De Jesus, A.R., Piloton, J.M., & Salem, Jr., R.R. (2019). Water Desalination System using Parabolic Trough with Varying Glass Thickness, *International Journal of Engineering and Advanced Technology*, ISSN: 2249-8958, Volume 9, Issue 1, Pages 6-11.
12. Dollera, E.B., Villanueva, E.P., Pabilona, L.L., Dotdot, K.J.A., & Dollera, Jr., G.B. (2019). Temperature Distribution in Mini Channel Heat Exchanger for the Development of a Portable Vaccine Carrier, *International Journal of Recent Technology and Engineering*, ISSN:2277-3878(Online), Volume-8 Issue-4, Pages 222-226.
13. Dollera, E.B., Golez Jr., R.C., Almedilla, J.R., Libao, F.B., & Talanda, F.M.C. (2019). Central Processing Unit Binary Cooling System using Tetraflouroethane as Refrigerant, *International Journal of Innovative Technology and Exploring Engineering*, ISSN: 2278-3075, Vol 9, Issue 2, Pages 1607-1612.
14. Dollera, E.B., Dablo, C.F.C., Dollera,Jr., G.B., Nasara, H.O., & Maquiso, K.B.A. (2019). Choke Point in Mini Expansion Device for the Development of Portable Vaccine Kit, *International Journal of Engineering and Advanced Technology*, ISSN: 2249-8958, Vol 9, Issue 2, Pages 3387-3393.
15. Dollera, E.B., Co, J.K.Y., Dotdot, K.J.A., Gamotin, J.L.A., & Mobida, D.J.P. (2020). Mini Channel Evaporator as MAC Device for Laptop Cooling System, *International Journal of Recent Technology and Engineering*, ISSN:2277-3878(Online), Volume-8 Issue-5, Page 2993-2998.

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