Improved Efficiency and Temperature Control in Single Evaporator Domestic Refrigerators: A Study of the Impact of Thermostatic Expansion Valves

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Abstract. Energy efficiency efforts and proper temperature control in domestic cooling systems are important in the world of domestic refrigeration. This can be done in several ways, such as changing the refrigerant used or replacing the expansion device currently used. This study investigates the potential benefits of integrating a thermostatic expansion valve (TEV) with the aim of improving energy efficiency, temperature stability and extending system life. From the literature review that has been carried out, TEV offers significant advantages over installed capillary pipe systems, including improved refrigerant flow regulation, optimal evaporator performance, and good temperature management. Additionally, TEV facilitates adaptive control mechanisms, allowing the refrigerator to adjust operation based on varying load conditions, ambient temperature and user preferences which has a significant impact on reducing energy consumption, minimizing temperature fluctuations and extending compressor life. This research will be carried out using an experimental method by comparing the work of the two expansion devices. By analyzing data collected from experiments and calculations in the coefficient of performance (COP) software, the performance and electrical energy efficiency of the two expansion devices can be identified and compared so that it can offer practical guidance for refrigerator manufacturers and designers.

Keywords: Capillary Tube, Coefficient of Performance, Single Evaporator Unit Domestic Refrigerator, Thermostatic Expansion Valve

1 Introduction

Refrigerators, today can be said to be a major necessity. The refrigerator can store food in ready-to-eat form or the ingredients of the food itself. Another function of the refrigerator is to make ice which can be used as a complementary ingredient to drinks. The main components of a refrigerator are the compressor, evaporator, expansion device, and condenser. The expansion device commonly used in a domestic refrigerator is a capillary pipe where this device functions to reduce the refrigerant pressure from the high to the low side, regulating the amount of refrigerant flow rate (Handoyo & Lukito, 2002; Jung et al., 1999; Kritsadathikarn et al., 2002; Sainath et

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al., 2019). Seeing this, the author wants to see the phenomenon that occurs if the capillary pipe is replaced with another type of expansion device such as a thermostatic expansion valve or automatic expansion valve (TEV). As has been mentioned about the function of the expansion device, the author wants to look at another thing, namely the energy use of the refrigerator if the expansion device is changed/replaced.

The current refrigerators have certain models and types and currently, there is no trainer unit at the Refrigeration and Air Conditioning Study Program, Bali State Polytechnic as a learning aid/practical tool where this tool will help students understand the parts of the refrigerator and learn about the damage that may occur, i.e repair, maintenance and retest the function of the refrigerator. Another thing that we want to achieve apart from creating a trainer unit is to open students' insight that opening a refrigerator repair service is quite a promising job. Many previous studies have been carried out to reduce the need for electricity. As (Aziz, 2013; Dharma, 2018; Fazri & Maryanti, 2016; Wiratmaja et al., 2022) said the same thing that the potential use of thermostatic expansion valves as a replacement for capillary pipes in domestic refrigeration machines is very possible because it will provide better cooling, lower electrical energy usage, and lower working temperature. Other research close to look over this subject have conduct like (Fazri & Maryanti, 2016; Kritsadathikarn et al., 2002; Made Susila et al., n.d.; Siregar et al., 2016) said that the use of a thermostatic expansion valve produces a better Coefficient of Performance and Energy Efficiency Ratio (EER) followed by lower working pressure and temperature. Another thing that can be found in previous research is that the use of thermostatic expansion valves is only at the research stage but not yet at the implementation stage in refrigerators which are widely used by the public.

In this research, the researcher wants to conduct applied research where this research will try to directly compare these two types of expansion devices on a trainer unit. Reducing the temperature and pressure of the liquid after the condenser will be carried out by an expansion device and this tool will function to expand adiabatically the high pressure and temperature refrigerant liquid from the condenser until the pressure and temperature are low (Aziz, 2013). The expansion device is a capillary pipe and a type of thermostatic expansion valve (Thermostatic Expansion Valve/TEV) where this tool will automatically regulate the amount of refrigerant that will enter the evaporator.

2 Methodology

This research is initial research for single evaporator domestic refrigerator units. This stage is divided into several processes such as the system design and design process which consists of studying the use of capillary pipes which is then followed by testing to determine the performance and electrical power used. The next stage is to replace the capillary tube with a thermostatic expansion valve, which is then tested for performance and the electrical power used. When collecting data, it will be carried out using an Android-based data logger which is assembled by yourself to make data retrieval easier and minimize errors that occur. After getting the data, the next step is

data processing using the Coolpack application to get the COP from each system and analyze electrical power usage

3 Result and Discussion

3.1 Result

The results and outcomes that have been achieved are a unit of modified refrigerator domestic single evaporator refrigerator which has installed 3 types of expansion devices namely: 0.26-inch capillary pipe with a length of 2000 mm, and also 0.36 mm capillary pipe in the same length and a thermostatic expansion valve (TEV). This tool has undergone several improvements, especially when looking for vacuum conditions in piping systems. Another thing that can be studied as an outcome is the combination of expansion valve material made from aluminum with copper pipes which is a series of piping in this refrigerator.

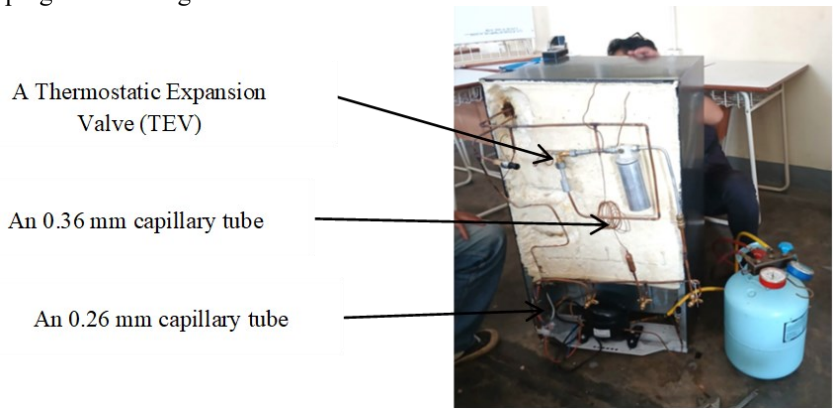

Figure 1. A modified refrigerator unit

The purpose of this test is to find temperature data and compare the performance of the three expansion devices that will be compared. The steps in testing and data collection are carried out by measuring the temperature of T1 (temperature out evaporator), T2 (temperature out compressor), T3 (temperature out condensor), T4 (temperature out evaporator), T5 (temperature inside evaporator/freezer), T6 (temperature inside refrigerator/cabin), PH (high pressure), PL (low pressure), on each expansion device with and without cooling load. The expansion devices will be opened in turn starting from expansion devices 1, 2, to 3 to compare the achievement of temperature in cooling the refrigerator unit for 1 hour (60 minute). After that, the data obtained will be processed and analyzed using Refrigerant Slider and Coolpack software to obtain the COP (coefficient of performance) value from the use of the expansion device.

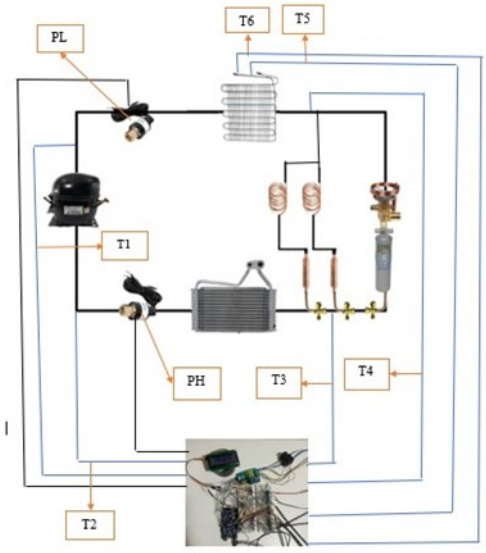

Figure 2. Image of piping and installation of trainer unit with measuring point

From the data been achieved shows us that both of capillary tube had a good performance as shown in the graph below even with or without load.

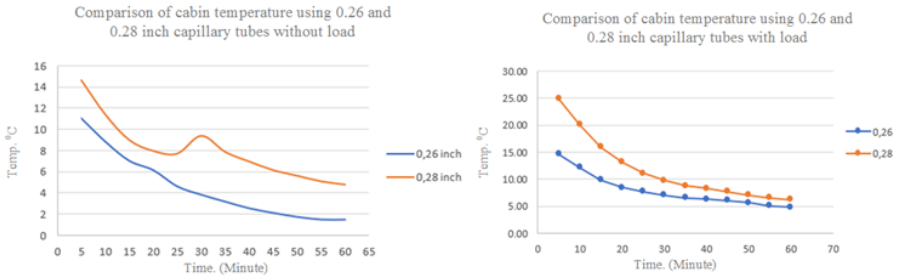

Figure 3. Ratio of temperature achievement in 2 capillary tubes with and without load

From Figure 3, we can show that the cabin temperature using a 0.26-inch capillary tube with a length of 200 cm will be cool much faster than a 0.28-inch capillary tube with a length of 200 cm. This also occurs when measurements are taken by adding a 2-liter load to the cabin as seen in the second graph (right figure).

In the capillary tube test, different test results and COP were also obtained even though the 2 capillary tubes had been calculated using the Danfoss application so recommendations for capillary tubes with diameters of 0.26 mm and 0.28 mm were obtained. Although the capillary tubes have different sizes, this can be done but on condition that more careful calculations are carried out and the test data shows that the optimal temperature can still be achieved and the COP value is still in an insignificant difference. The COP value for each capillary tube test of 0.26 without

load produces 4.4 and with load produces 4.3. While the capillary tube test of 0.28 without load produces 4.1 and with load produces 4.1

It's a different story with using a thermostatic expansion valve (TEK). From the test results and calculations, it did not produce the desired temperature and COP. This is clearly seen in the graph below.

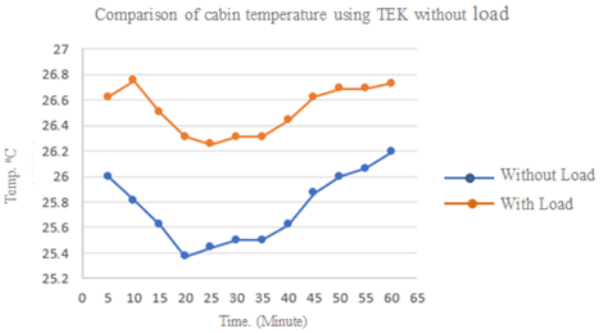

Figure 4. Temperature achievement in thermostatic expansion valve (TEK)

From the Figure 4, it is clear that the desired temperature is below 5ºC but in the test, the lowest temperature achieved was 25ºC even with a test time of 60 minutes a very significant increase in temperature was seen. This is likely because the TEK used has a minimum working pressure above ± 25 psi while the compressor working on the single evaporator refrigerator works with a pressure capacity of ± 10 psi.

3.2 Discussion

From the data that has been processed and analyzed, it can be seen that the COP value shows a comparison of values that are not too striking between 2 different expansion valves, where the largest COP value is 4.4 while the smallest value is 4.1 and can be said that the use of expansion valves with sizes 0.26 and 0.28 with the same length will produce the same performance. Different results are shown in the use of thermostatic expansion valves where the use of this valve is greatly influenced by the amount of pressure produced by the compressor. At this time, the smallest thermostatic expansion valve uses a pressure above 20 psi. Seeing this, the use of an expansion valve in a single evaporator refrigerator is highly discouraged considering the use of a compressor that only produces a pressure of less than 20 psi.

4 Conclusion

From the performance test data from the Trainer Unit Refrigerator using 2 capillary tubes with different diameters and a thermostatic expansion valve with a compressor size of 1/8pk, it was found that the use of a capillary tube with a smaller diameter of 0.26 inches was much better than 0.28 inches. The difference is the time to achieve

the cabin temperature and evaporator temperature. In the thermostatic expansion valve test, a bad thing was obtained where the cabin temperature and evaporator were not achieved at all and this was caused by the pressure capacity of the compressor below 20 psi.

References

Aziz, A. (2013, November 27). *Komparasi katup ekspansi termostatik dan pipa kapiler terhadap temperatur dan tekanan mesin pendingin*. https://doi.org/10.13140/RG.2.1.1151.4005

Dharma, B. (2018). Karakteristik laju pendinginan dan coeffient of performance KTE-2000EV menggunakan katup ekspansi otomatis dan katup ekspansi termostatik. *Jurnal Rekayasa Material Manufaktur Dan Energi*, *1*(1), 12–19. https://jurnal.umsu.ac.id/index.php/RMME/article/view/2431

Ekadewi Anggraini Handoyo, & Lukito, A. (2002). Analisis pengaruh pipa kapiler yang dililitkan pada line suction terhadap performansi mesin pendingin. *Jurnal Teknik Mesin*, *4*(2), 94–98.

Fazri, A., & Maryanti, B. (2016). Analisa karakteristik katup ekspansi termostatik dan pipa kapiler pada sistem pendingin water chiller. *JTT (Jurnal Teknologi Terpadu)*, *4*(1), Article 1. https://doi.org/10.32487/jtt.v4i1.124

Jung, D., Park, C., & Park, B. (1999). Capillary tube selection for HCFC22 alternatives. *International Journal of Refrigeration*, *22*(8), 604.

Kritsadathikarn, P., Songnetichaovalit, T., Lokathada, N., & Wongwises, S. (2002). Pressure distribution of refrigerant flow in an adiabatic capillary tube. *Sci Asia, 28, 71-76.*

Sainath, K., Kumar Reddy, T. K., & Akella, S. (2019). Optimization of capillary tube dimensions using different Refrigerants for 1.5 ton mobile air conditioner. *Case Studies in Thermal Engineering*, *16*, 100528. https://doi.org/10.1016/j.csite.2019.100528

Wiratmaja, I. G., Widayana, G., & Elisa, E. (2022). Analisis pengaruh variasi jarak katup ekspansi dengan kondensor terhadap laju pendinginan ruangan dan COP mesin pengkondisian udara tipe split air conditioning. *Jurnal Pendidikan Teknik Mesin Undiksha*, *10*(1), Article 1. https://doi.org/10.23887/jptm.v10i1.45806