2301-9069 (e)
1829-8370 (p)

Kapal: Jurnal Ilmu Pengetahuan dan Teknologi Kelautan
(Kapal: Journal of Marine Science and Technology)

journal homepage : http://ejournal.undip.ac.id/index.php/kapal

Modification of Double Helical Kapiler Pipe to Reduce Temperature in a 100 Liter Capacity Freezer on the Ship

Urip Prayogi[1)*)], Frengki Mohamad Felayati[1)], Erik Sugianto[1)], Muhammad Rizal Syaifuddin[1)]

[1)] Department of Marine Engineering, Universitas Hang Tuah, Surabaya 60111, Indonesia
[*)] Corresponding Author: yogi@hangtuah.ac.id

Article Info

Keywords:
Freezer;
Capillary Pipe;
Double Helical;
Coefficient of Performance (COP);

Article history:
Received: 17/05/2024
Last revised: 24/06/2024
Accepted: 07/07/2024
Available online: 07/07/2024
Published: 11/07/2024

DOI:
https://doi.org/10.14710/kapal.v21i2.63798

Abstract

The freezer machine is one of the tools on board and serves to maintain the temperature of food ingredients to keep it in good condition and fresh. Given the importance of this, the cooling machine is a tool that functions to make durable foodstuffs by naturally maintaining the temperature. Standard freezer machines produce temperatures only up to -15°C. Modification of the freezer machine needs to be done so that the temperature reaches a lower minus again by changing the capillary pipe from standard to double helical. The purpose of this study is to analyze the effect of double helical capillary pipes on the working performance of a 100-liter capacity freezer cooling machine using R600A refrigerant. In this study the frezzer machine was modified by replacing a single capillary pipe into a double helical. The method used is to conduct experiments to take data to determine the temperature produced and calculate the Coefficient of Performance (COP) before and after modification. The results of this study are the lowest temperature in the double helical capillary pipe variation during the three-hour test obtained a temperature in the range of -20.2oC while the standard capillary pipe obtained a temperature in the range of -14.9°C. The average COP for standard capillary pipes is greater at 2.773 compared to the COP of double helical capillary pipes which is 2.421. At double helical temperature values are cooler than standard capillary pipes. However, the disadvantage is that the COP of the double-helical capillary pipe is lower than the COP of the standard capillary pipe.

1. Introduction

The cooling machine is one of the tools on the ship and serves to maintain the temperature of food ingredients to keep them in good condition and fresh. Food is very important on the ship because one of the basic human needs is food. Given this importance, a cooling machine is a tool that makes durable foodstuffs by naturally maintaining the temperature. Given the important role of the cooling machine, the maintenance of the ship's cooling machine needs special attention so that it is always ready to use and work properly to support operational conditions in shipping [1]. Reduced cooling performance in refrigeration systems can be caused by a variety of factors, which are often interrelated. One important relationship to note is between the choice of capillary tubing and the type of refrigerant used. Each type of refrigerant has different physical and thermodynamic characteristics. For example, high-viscosity refrigerants require capillary tubing with a larger diameter for optimal flow. Some refrigerants work more efficiently within certain temperature ranges. The choice of refrigerant that does not match the environmental conditions can degrade system performance.

Research on the flow of R407C in adiabatic helical capillary tubes was conducted using experimental methods. The results are for the mass flow rate of R407C through straight and circular geometry capillary tubes. Compared to the mass flow rate of R407C in straight capillary tubes, the mass flow rate in coiled capillaries with coil diameters of 60 mm, 100 mm, and 140 mm was reduced by an average of 10 percent, 7 percent, and 5 percent. The correlation developed for the mass flow rate resulted in good agreement with the measured data from this study with a deviation of 10 percent [2].

Another study on the variation of the diameter of the double-helical capillary pipe on the working performance of the cooling machine using LPG refrigerant using the experimental method obtained a COP (Coefficient of Performance) result owned by a double helical capillary pipe with a diameter of 0.026 inches is the largest COP of 8.99. The smallest COP is obtained at a diameter of 0.028 which is 5.98. The use of double helical capillary pipes with a diameter of 0.026 inches can increase the COP of the cooling machine by 2.2% of the standard cooling machine [3].

Research on analyzing the decline in refrigerator performance in order to maintain the quality of food ingredients on the MV. SPIL NIKEN using a qualitative descriptive method, the results obtained were freon leaks in the low-pressure pipe after the evaporator. Freon leakage in the low-pressure gas freon pipe will cause the amount of freon in the system to decrease which results in less freon being expelled in the evaporator so that it is unable to make the cooling room cool. Temperature increase in seawater cooling in the condenser. The high temperature of seawater cooling in the condenser, namely 55ºC, can be caused because the seawater cooling pipe in the condenser is dirty, interfering with the process of cooling freon gas into liquid [4].

In the research study of the performance comparison of refrigerant R134A with R600A using descriptive methods. The result is that the COP value of R134A is slightly higher than 0.1 of R600A, thus R600A can replace the work of R134A, The difference between R134A and R600A power is 138.6 watts, so the power consumption for R600A is smaller than R134A, The amount of R134A usage is more than R600A, with a difference in usage of 320 grams, In addition, the price of R134A is more expensive than R600A so it can be concluded that R600a is more economical in use and cheaper in price, the faster the rotation of the evaporator fan blower, the faster the cooling process in the cabin. Furthermore, the analysis of the decline in the performance of food cooling machines to maintain the temperature in the freezer and chiller on the AHTS MP PROSPER Ship using qualitative methods [5].

The result is the slowness of the cooling machine to reach the desired temperature, the cause is the entry of lubricating oil into the cooling system. The way to handle the entry of lubricating oil into the cooling system is by cleaning the system in the pipes by spraying freon R11, the pressure on the suction and press manometers is too low caused by a leak in the high-pressure pipe nipple. To overcome the leak, soldering can be done on the leaking pipe parts [6].

Regarding the analysis of seaworthiness and safety regulations on the installation of freezer refrigeration equipment on fishing vessels using qualitative descriptive methods. Based on the aim to identify and analyze regulations or legal rules, regarding the supervision of the installation of freezer refrigeration equipment and regulations governing the competence of freezer installation workers and the authorities that oversee their work. The result is that the legal umbrella or government policy governing the installation of freezer refrigeration equipment on fishing vessels does not yet exist, so the installation of freezers on fishing vessels has not received special attention from the government, both direct supervision and regulations that regulate it, strengthened by the absence of licensing from related agencies. Standard operating procedures in supervising the installation of freezers do not yet exist because the legal umbrella or government policy does not yet exist and such supervision is needed considering that the work of installing and using freezers continues to increase and is needed for ships with tonnage GT. 88 and above with Indonesian shipping areas to store fish catches and maintain the freshness and quality of fish [7]. Further research on the experimental study of TiO2-R600a nano refrigerant as a future refrigerant using experimental methods. Based on the aim is to determine the optimum concentration of TiO2 and obtain hydrocarbon refrigerants with the best performance that can be used as a refrigerant option in the future. The results show that R600A + TiO2 can be used as a safe and efficient refrigerant without any modification of the refrigerator, TiO2 increases the thermal conductivity and heat transfer of the refrigerant, from 5 independent variables, the best performance is obtained at TiO2 levels of 1 g/L (COP = 4.821) [8].

Furthermore, research on the Coefficient Of Performance (COP) mini chicken meat freezer capacity of 4 Kg using experimental methods. The results showed that the highest actual COP was 3.65, at 14.00-15.00 and the lowest was 2.9, while the highest Carnot COP was 5.8 at 14.00-15.00, and the lowest Carnot COP was 5.3 at 16.00-17.00, the highest efficiency was 61% at 14.00-15.00 and the lowest was 54% at 16.00-17.00 [9].

In research on the position of fish laying on cold air circulation in cool boxes on purse seine vessels using Computational Fluid Dynamics, the results of simulation and analysis of cool box models with two load variations in them using Computational Fluid Dynamics show that the best fluid flow velocity contour is 22.0 m/s in storage with longitudinal alignment, and the highest speed is 24.4 m/s in storage with the position of the fish arranged crosswise. Two load variations inside the cool box were compared using Computational Fluid Dynamics software to simulate the temperature distribution. The results showed that model 1 (fish in longitudinal alignment) was the best storage, with temperatures getting cooler from the top to the bottom, namely 271 K (-2ºC), 268 K (- 5ºC), 266 K (-7ºC). However, the temperature inside the cool box in storage with model 2 (fish arranged crosswise) did not reach the maximum peak, so the resulting temperature from top to bottom rose with temperatures of 265 K (-7ºC), 268 K (-5ºC), 271 K (-2ºC). To achieve the optimal temperature in the cooler box, it is recommended to use storage with model 1, namely by placing the fish parallel and in the same direction [10].

In contrast to the studies described above, this study uses an experimental method by experimenting with a standard capillary pipe comparison freezer with double helical using R600a refrigerant. The results of this study are expected to double helical capillary pipes cause a pressure drop in the capillary pipe to be large, thus increasing the temperature difference and reducing the lower temperature inhibits bacterial growth and maintains food quality longer.

2. Methods

This research method is carried out by experimenting by replacing the standard capillary pipe with a double helical capillary pipe freezer with a capacity of 100 liters. This research begins with collecting preliminary data in the form of measurements of temperature, pressure and so on the standard capillary pipe freezer. To determine the working pressure of the freezer, a pressure gauge is installed on the high pressure (red color) and low pressure (blue color) parts. Meanwhile, to measure the temperature, a thermogun is used which is directed to the test points. Next, modify the standard capillary pipe into double helical with R600A refrigerant. Then data collection was carried out after modification including measurement of pressure, temperature and so on. Standard capillary pipe data and double helical capillary pipe data are then analyzed to compare the resulting temperature and COP of both. The results of the research and analysis will get a deeper understanding of the use of double helical capillary pipes than standard capillary pipes, especially COP and temperature.

2.1. Experiment Setup

This research is used to test and evaluate the performance of a freezer. In this study the freezer used has a capacity of 100 liters, which can be seen in Figure 1 and specifications can be seen in Table 1.

Figure 1. Freezer capacity of 100 liters

Table 1. Freezer Specifications

Items	Specifications
Model	Chest Freezer
Type	HS-131CNK
Power	100 watts
Voltage	220 - 240 V
Frequency	50 Hz
Size	578x520x888mm
Weight	23.9 kg
Cooling Capacity	100 liters
Country of Manufacture	China

The first step of this research is to prepare materials and equipment. The preparation of materials and equipment that will be used to carry out the test is presented in Table 2.

Table 2. Research Instruments

Tool Name	Type	Specifications
Pressure Gauge	Rg-250 Analog	0-35 Bar
Manifold Gauge	Ersr22	0-15 Bar
Thermogun	Ti-600	-50-600 Oc
Ampere Meter Pliers	Dt 266	200a-1000a
Vacuum Pump	Vp125	1/3 Hp
Leak Detector	Xl-1	< 3g/Year

2.2. Testing Condition Strategy

There are two type capillary tube used in this experiment, first was standard capillary tube (one capillary) (Figure 2) and second was double helical capillary pipe (two capillary) (Figure 3). Each capillary pipe used was 30 cm long of copper material, this was chosen due to its high heat conductivity properties, ensuring efficient heat transfer. The sufficient length of the pipe provides a long path for optimal cooling. A diameter of 0.026 inches was chosen so that the refrigerant flow can be regulated with precision, increasing cooling efficiency. In operation, the capillary pipes are in charge of converting the refrigerant into liquid and gaseous forms at regular intervals, creating an effective refrigeration cycle to keep the temperature in the freezer stable and meet the storage needs in a 100-liter capacity.

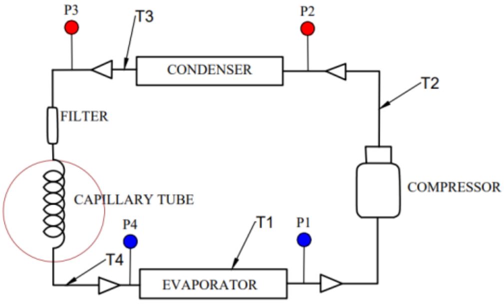

Figure 2. Standard Capillary Tube

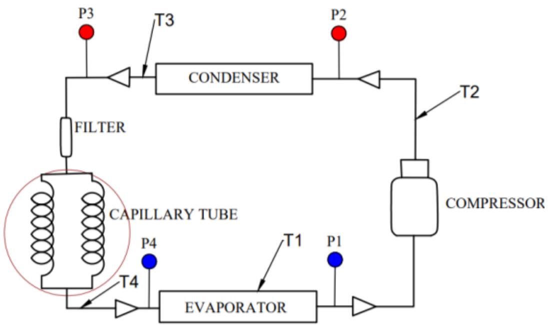

Figure 3. Double Helical Capillary Pipe

2.3. Cooling Engine Performance Calculation

The refrigerant flow rate in the freezer can be calculated using the measured electrical power of the compressor. The electrical power of the compressor is known by measuring the current and voltage entering the compressor. The amount of electrical power is calculated by Equation 1-5.

- Compression Process (W_{in})

$$Win = H2 - H1 \quad (1)$$

where,
H1: Evaporator output enthalpy, kJ/kg ; H2: Condenser input enthalpy, kJ/kg

- Compressor Power (Wk)

$$Wk = I \times V \quad (2)$$

where,
Wk: compressor power, W; I: electric current, A; V: electrical voltage, V

- Mass flow rate (m)

$$Wk = m\,(H2 - H1)$$
$$m = \frac{Wk}{(H2 - H1)} \quad (3)$$

where,
m: mass flow rate, kg/s

- Cooling Capacity (Qin)

$$Qin = m\,(H1 - H4) \quad (4)$$

where,
Qi : cooling capacity, kW ; H4 : evaporator input enthalpy, kJ/kg

- COP (Coefficient of Performance)

$$COP = \frac{Qin}{Wk} \quad (5)$$

3. Results and Discussion

The data that has been taken is used to analyze the performance, temperature, pressure, and COP of the R600a refrigerant in a 100-liter capacity freezer.

3.1. Freezer Testing Results

The experiment was carried out 3 times in the hope of getting correct and valid results. The experiments obtained are as below:
- T1 : Temperature after evaporator.
- T2 : Temperature after the compressor.
- T3 : Temperature after condenser
- T4 : Temperature after expansion.
- P1 : Pressure before compressor.
- P2 : Pressure before condenser.
- P3 : Pressure before expansion.
- P4 : Pressure before evaporator.

Table 3. shows the average test results of the above three tests on freezers with standard capillary pipes. It can be seen that the evaporator and expansion T out decreases with increasing time. This shows that the refrigerant evaporation process takes place well and absorbs the heat of the air to be conditioned. Meanwhile, the T out of the compressor and condenser increases with increasing time. This shows that the compression and condensation of the refrigerant require work from outside and release heat to the surrounding air. In addition, the high pressure fluctuates with increasing time. This shows that the refrigerant pressure fluctuates due to phase changes and refrigerant temperature in the refrigeration machine cycle.

Table 3. Average data of standard capillary pipe testing

Time (minutes)	T1 (ºC)	T2 (ºC)	T3 (ºC)	T4 (ºC)
15	-7,1	45,5	36,3	9,1
30	-8,6	48,1	42,4	6,2
45	-9,9	50,6	44,3	4,2
60	-11,1	52,7	47,7	2,3
75	-11,6	54,6	49,9	-0,3
90	-12,6	55,9	50,8	-1,7
105	-13,1	57,5	51,6	-2,7
120	-13,6	58,2	52,9	-3,6
135	-14,2	59,8	53,9	-4,6
150	-14,5	60,6	54,3	-5,3
165	-14,7	63	54,8	-6
180	-14,9	63,6	55,3	-6,7

Table 4. shows the average test results of the above three tests on the freezer with double helical capillary pipes. It can be seen that the evaporator and expansion T out decreases with increasing time. This shows that the refrigerant evaporation process takes place well and absorbs the heat of the air to be conditioned. Meanwhile, the T out of the compressor and condenser increases with increasing time. This shows that the compression and condensation of the refrigerant require work from outside and release heat to the surrounding air. In addition, the high pressure fluctuates with increasing time. This shows that the refrigerant pressure fluctuates due to phase changes and refrigerant temperature in the refrigeration machine cycle.

Table 4. Average data of double helical capillary pipe testing

Time (minutes)	T1 (ºC)	T2 (ºC)	T3 (ºC)	T4 (ºC)
15	-11,5	37,4	31,1	2,4
30	-15	43,8	33,9	1,3
45	-16,1	48,8	38	-1,2
60	-16,7	54,2	41,7	-3,2
75	-17,6	56,6	38,8	-5,7
90	-18,3	55,3	43,1	-6,8
105	-18,6	55,4	43,4	-7,5
120	-19,1	55,4	43,7	-8,2
135	-19,3	56	42,5	-8,6
150	-19,5	53,4	42,9	-9,7
165	-19,8	55,6	46,8	-13,3
180	-20,2	54,2	45,8	-14

3.2. Calculation of COP (Coefficient of Performance)

After conducting several tests and obtaining the results of the tests used to calculate and determine the COP of standard and double helical capillary pipes, the calculation of the Coefficient of Performance (COP) in the freezer involves a comparison between the cooling power generated by the freezer and the electrical power used, an example of the calculation can be seen as below. Standard capillary pipe COP calculation at minute 15.

- T1 = -7.1 ° C
- T2 = 45.5 ° C
- T3 = 36.3 ° C
- T4 = 9.1 ° C
- P1 = 0.2 Bar
- P2 = 6.2 Bar
- P3 = 6.2 Bar
- P4 = 0.2 Bar
- H1 = 551 kj/kg
- H2 = 620 kj/kg
- H3 = 290 kj/kg
- H4 = H3 = 290 kj/kg

Compression Process (Win)

Win = H2 - H1

= 620 - 551 = 69 Kj/Kg

Compressor Power (Wk)= I x V

Wk = I x V

= 0.2 A x 220 V
= 44 Watts = 0.044 Kj/s
Mass flow rate (m)
m=Wk/(H2-H1) =(0.044 Kj/s)/(69 Kj/Kg) =0.000637 Kg/s
Cooling Capacity (Qin)
Qin = m(H1 - H4)
= 0.000637 kg/s (551 Kj/kg- 290 Kj/kg)
= 0.000637 kg/s (261 Kj/kg)
= 0.166257 Kw
COP (Coefficient of Performance)
COP =Qin/Wk=(166.257 W)/(44 W) = 3.77

Table 5. COP comparison data of standard capillary pipe with double helical

Time (minutes)	COP Standard Capillary Pipe	COP Double Helical Capillary Pipe
15	3,77	2,58
30	3,93	3,29
45	3,04	2,89
60	3,21	2,35
75	2,62	2,26
90	2,52	2,2
105	2,5	2,35
120	2,28	2,15
135	2,22	2,34
150	2,035	2,58
165	2,038	2,04
180	2,119	2,027
Average	2,773	2,421

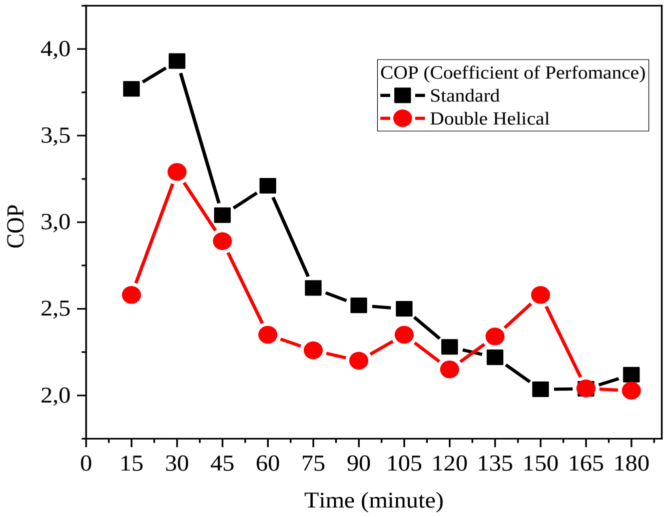

Figure 4. COP Comparison Chart

In Table 5 and Figure 4, the results of the COP calculation show that using standard and double helical capillary pipes at 15 minutes to 30 minutes has increased. While at 30 to 90 minutes, double helical seems to experience a decrease in COP of 3.29 to 2.2. The standard capillary looks more likely to experience a periodic decline from minutes 60 to 150 with a COP of 3.21 to 2.035 and then increases again at minutes 150 to 180 minutes with a COP of 2.035 to 2.119. COP values are not always the same under load conditions all the time. This value can change due to various factors. The main factor that affects because the value of heat energy absorbed by the evaporator per unit mass of refrigerant is not fixed (Qin) or the compressor work is always changing [11]. When viewed based on the average comparison of the graph above the double helical COP work is lower than the standard COP. A higher COP has the effect of lower operating costs and less environmental impact [12].

3.3. Calculation of COP (Coefficient of Performance)

The standard capillary pipe freezer temperature graph with double helical can be seen in Figure 5 obtained from the standard capillary pipe temperature comparison data with double helical presented in Table 6. From the graph, it can be seen that the double helical capillary pipe freezer temperature is lower than the standard capillary pipe freezer temperature at each measurement time.

In the first test (standard capillary tube), the temperature decreased significantly from -7.1 °C to -14.9 °C, from the 15th minute to the 180th minute. Meanwhile, the second test (double helical capillary pipe) also experienced a decrease in temperature from -11.5 °C to -20.2 °C, from the 15th minute to the 180th minute. This shows that double helical capillary pipes can provide better and faster cooling than standard capillary pipes. Double helical capillary pipes are claimed to increase the refrigerant flow rate and reduce friction losses compared to standard capillary pipes [13]. The capillary pipe functions as an expansion device to reduce the pressure and temperature of the refrigerant before entering the evaporator. The shape and size of the capillary pipe can affect the performance and efficiency of the refrigeration system. Thus, double helical capillary pipes can be a better alternative to standard capillary pipes for small-scale refrigeration systems.

Table 6. Evaporator Temperature Comparison Data on Standard and Double Helical Capillary Pipes

Time (minutes)	Temperature of Capillary Pipe Standard (°C)	Temperature of Double Helical Capillary Pipe (°C)
15	-7,1	-11,5
30	-8,6	-15
45	-9,9	-16,1
60	-11,1	-16,7
75	-11,6	-17,6
90	-12,6	-18,3
105	-13,1	-18,6
120	-13,6	-19,1
135	-14,2	-19,3
150	-14,5	-19,5
165	-14,7	-19,8
180	-14,9	-20,2

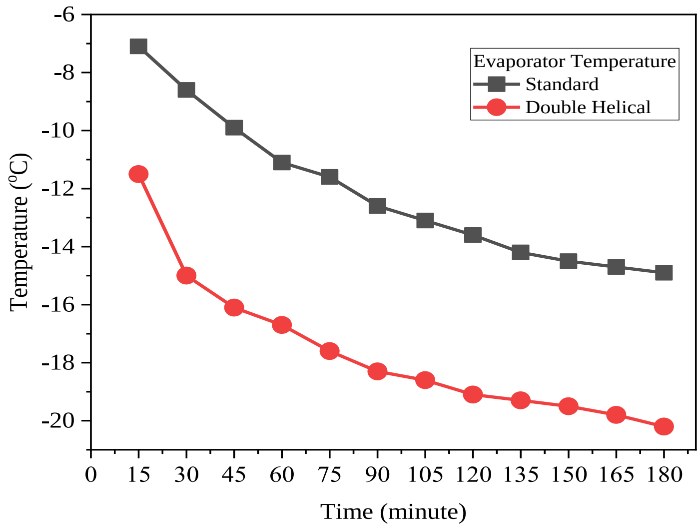

Figure 5. Evaporator Temperature Comparison

3.4. Temperature Analysis after Compressor

The temperature graph after the standard capillary pipe freezer compressor with double helical can be seen in Figure 6 obtained from the standard capillary pipe temperature comparison data with double helical presented in Table 7. From the graph, it can be seen that the temperature after the double helical capillary pipe freezer compressor is lower than the temperature after the standard capillary pipe freezer compressor at each test time.

The installation of double helical capillary pipes in freezers can cause a decrease in compressor temperature due to the increase in pipe length and increased friction in the system. The double helical structure tends to create more flow resistance, reducing cooling efficiency and increasing the workload on the compressor. This can result in an undesirable temperature drop in the freezer cooling process.

An increase in pipe length can be a major factor causing a decrease in compressor temperature. The double helical structure increases the effective length of the pipe, which directly increases the fluid flow resistance. As a result, the pressure in the system increases, forcing the compressor to work harder to achieve the desired temperature. This increase in pipe length can also cause a drop in pressure and temperature at the end of the pipe, reducing the overall cooling efficiency.

The installation of double helical capillary pipes in refrigeration machines can cause a decrease in compressor temperature due to increased pipe length, additional friction, and changes in refrigerant flow patterns. To maximize refrigeration efficiency and performance, it is necessary to make appropriate design adjustments to overcome these challenges [14].

Table 7. Comparison Data of T out of Standard and Double Helical Compressors

Time (minutes)	Temperature of Capillary Pipe Standard (°C)	Temperature of Double Helical Capillary Pipe (°C)
15	45.5	37.4
30	48.1	43.8
45	50.6	48.8
60	52.7	54.2
75	54.6	56.6
90	55.9	55.3
105	57.5	55.4
120	58.2	55.4
135	59.8	56
150	60.6	53.4
165	63	55.6
180	63.6	54.2

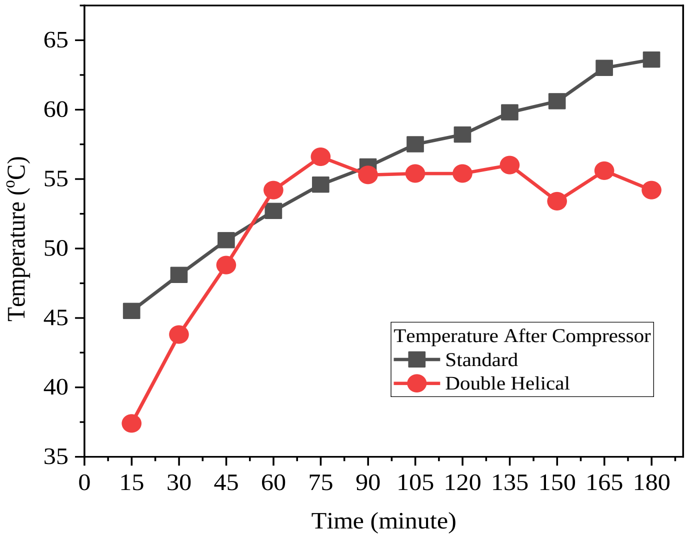

Figure 6. Temperature Comparison After Compressor

3.5. Temperature Analysis after Condenser

The temperature graph after the standard capillary pipe freezer condenser with double helical can be seen in Figure 7 obtained from the standard capillary pipe temperature comparison data with double helical presented in Table 8. From the graph, it can be seen that the temperature after the double helical capillary pipe freezer compressor is lower than the temperature after the standard capillary pipe freezer condenser at each test time.

The installation of double helical capillary pipes in the freezer condenser has a significant impact on the refrigeration efficiency and condenser temperature. A more detailed analysis of the cause of the temperature drop can involve several aspects, including the structure of the double capillary pipe, heat transfer characteristics, and other factors that affect the performance of the refrigeration system.

The positive effect of installing double helical capillary pipes is an increase in the overall efficiency of the refrigeration cycle. With more surface area, heat can be quickly transferred from the refrigerant to the air, optimizing the cooling process. In addition, the use of a double helical structure can help reduce airflow resistance along the pipe, avoiding potential bottlenecks that could reduce refrigeration performance [15].

By using a double helical capillary pipe, the pressure and temperature of the refrigerant leaving the compressor will decrease faster and more than using a regular capillary pipe. This is due to the higher surface area, heat transfer coefficient, and turbulence effect in the double helical capillary pipe [16]. As a result, the temperature of the freezer condenser will also decrease, as the refrigerant entering the condenser has a lower temperature than the refrigerant using a regular capillary pipe.

Table 8. Comparison Data of T out of Standard and Double Helical condensers

Time (minutes)	Temperature of Capillary Pipe Standard (°C)	Temperature of Double Helical Capillary Pipe (°C)
15	36,3	31,1
30	42,4	33,9
45	44,3	38

60	47,7	41,7
75	49,9	42,3
90	50,8	43,1
105	51,6	43,4
120	52,9	43,7
135	53,9	42,5
150	54,3	42,9
165	54,8	46,8
180	55,3	45,8

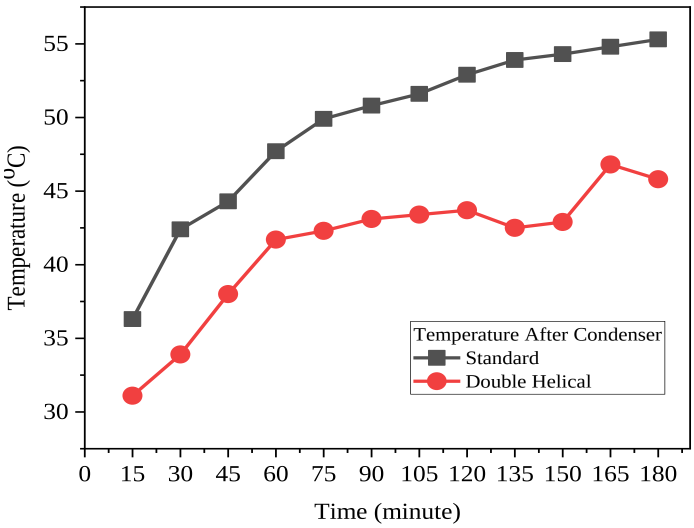

Figure 7. Temperature Comparison After Condenser

4. Conclusion

The conclusion of the research results of the modification of double helical capillary pipes in a 100 liter capacity freezer using R600A refrigerant, namely: The lowest temperature in the double helical capillary pipe variation during the 3-hour test obtained a temperature in the range of -20.2 °C while the standard capillary pipe obtained a temperature in the range of -14.9 °C. The average COP for the standard capillary pipe is greater at 2.773 compared to the double helical capillary pipe COP of 2.421. Comparison of standard capillary pipes with double helical affects the evaporator cooling capacity, compressor work, and temperature value in the evaporator. At double helical temperature values are cooler than standard capillary pipes. However, the disadvantage is that the double helical COP is lower than the standard. The higher the COP the more efficient the cooling machine works. If you prioritize efficiency and energy saving, choose a standard capillary pipe that has a higher COP. But if you prioritize cooling capacity and lower temperatures, choose a double helical capillary pipe that has better performance.

Acknowledgements

Our thanks go to all those who have supported this research, Hang Tuah University, especially the refrigeration machine laboratory of the Marine Engineering study program which has facilitated equipment to carry out experiments.

References

[1] Prayogi, U., Ciptadi, G., Widodo, Abdurrouf, "Comparative Analysis of Air Conditioning Performance with 0.5 PK Capacity Using Environmentally Friendly Refrigerants," *International Review of Mechanical Engineering Journal*, 16(12), 643-650, 2022.
[2] Mittal, M. K., Kumar, R., & Gupta, A, "An Experimental Study of The Flow Of R-407C In An Adiabatic Helical Capillary Tube," *International Journal of Refrigeration*, 33(4), 840– 847, 2014.
[3] Rahman, A," Recent Innovations in Refrigeration Machines: A Case Study on Energy Efficiency," *International Journal of Energy Efficiency*, 2023.
[4] Choudhari, C., Sapali, S., "Experimental Performance Analysis of Refrigerant R290 for Water Cooler Application," *International Review of Mechanical Engineering*, 11 (6),pp. 419-425, 2019.
[5] B. Sachuthananthan,T. Naresh Kumar, A.Muthu Manokar, "A Performance Of A Window Air Conditioner Using Alternative Refrigerants R134a And R600a," *International Journal of Engineering Sciences & Research Technology*, 10-13., 2019.
[6] Prayogi, U., Ciptadi, G., Widodo, Abdurrouf, " Risk Analysis of Using Refrigerant R-22 Substitute for Compressor of Air Cooling System Using Failure Mode and Effect Analysis (FMEA) Method" *International Journal on Engineering Applications Journal*, 11(2), 81-88, 2023.

[7] Purwantini, S., & Saraswati, I, " Analisis Regulasi Kelaiklautan Dan Keselamatan Terhadap Pemasangan Alat Pendingin Frezeer Pada Kapal Ikan," *Jurnal Sains Teknologi Transportasi Maritim*, 4(2), 12– 20, 2022.
[8] Sanukrishna, S.S., Murukan, M. and Jose, P.M., " An Overview Of Experimental Studies On Nanorefrigerants: Recent Research, Development And Applications," *International Journal of refrigeration*, 88, pp,552-577, 2018.
[9] Okido, T., Takigawa, K., Saito, " Development of Refrigeration Oil for Use with R32," *International Refrigeration and Air Conditioning Conference at Purdue*" , 2015.
[10] Prayogi, U., Sa' adah, N., & Muhammad, R. G. " Pengaruh Posisi Peletakan Ikan Terhadap Sirkulasi Udara Dingin Di Cool Box Pada Kapal Purse Seine Menggunakan Computational Fluid Dynamics (CFD)," *Zona Laut: Journal of Ocean Science and Technology Innovation*, vol. 4 no. 3, pp. 262– 271. (2023).
[11] Jadhav, Pravin, Neeraj Agrawal, "Comparative Study On A Straight And Helical Capillary Tube For CO2 And R22 Refrigerant," *Journal of Thermal Science and Engineering Applications* , vol. 13 no. 2, 2021.
[12] Ghani, Saud, et al, "Experimental Investigation of Double-Pipe Heat Exchangers In Air Conditioning Applications", *Journal Energy and Buildings* , vol.158, pp. 801-811, 2018.
[13] Colorado, D., Hernández, J. A., García-Valladares, O., Huicochea, A., & Siqueiros, J, " Numerical Simulation And Experimental Validation Of A Helical Double-Pipe Vertical Condenser, " *Applied Energy*, vol. 88 no. 6, pp. 2136-2145, 2017.
[14] Jadhav, P. and Agrawal, N., Comparative study on a straight and helical capillary tube for CO2 and R22 refrigerant. *Journal of Thermal Science and Engineering Applications*, 13(2), 2021.
[15] Salem, T.K., Farhan, S.S., Doury, R.R.J.A. and Farhan, I.S., "The Heat Exchangers Tubes Mineral Type Effect On The Refrigeration System Performance Using Different Lengths Of The Capillary Tube," *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, vol. 235 no. 22, pp.6541-654, 2021.
[16] Barzegari, H., Tavakoli, A., Jalali Vahid, D. and Bekhradinassab, E., "Experimental Study of Heat Transfer Enhancement in a Helical Tube Heat Exchanger by Alumina Nanofluid as Current Flow," *Heat and Mass Transfer*, vol. 55, pp.2679-2688, 2019.