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Air Blast Freezer Cooling System Performance Analysis Capacity ½ pk Using TXV Expansion and Capillary Pipe for Freezing Beef

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Abstract**—** *Air Blast Freezer is a refrigeration machine unit for rapid freezing that uses the method of blowing air as its cooling. Evaporator fan plays an important role in the performance of the evaporator in the Air Blast Freezer to freeze the product. The role of the fan is very influential to distribute air, circulate air, and regulate air velocity which can affect the cooling effect in the evaporator. The study was conducted to compare the air blast freezer system using a TXV (thermal expansion valve) expansion device using a capillary tube expansion device. The cooling machine uses R22 and has a capacity of pk with a cabin size of 60 cm x 60 cm x 100 cm. While the cooling load uses 3 kg of beef which is frozen to a temperature of -12 0C. The research data was taken by varying the frequency of the evaporator fan using an inverter from 30 Hz, 35 Hz, 40 Hz, 45 Hz, and 50 Hz. From the results of the study, the average cooling effect using TXV was 168.4 kJ/kg, and using a capillary tube was 166.6 kJ/kg. Specific compression work on average using TXV 37.1 kJ/kg, while using a capillary tube 46.8 kJ/kg. The coefficient of actual performance on average uses 4.6 TXV, while using a capillary tube 3.6. The average efficiency using TXV is 0.79, while using a capillary tube is 0.83.*

Keywords**—** *Air blast freezer, fan evaporator, thermal expansion valve, capillary tube, cooling effect.*

I. Introduction

The process of storing products (fish, meat, ready-to-eat foods, etc.) at low temperatures aims to inhibit, prevent, and stop the growth of microorganisms in the product, but to reach this low temperature (required low temperature) a certain period of time (chilling time) is required. . The shorter the chilling time, the growth of microorganisms in the product can be inhibited. The low temperature for product storage depends on the type of product to be stored. This low temperature not only inhibits the growth of microorganisms, but also inhibits the occurrence of damage to the texture of the product so that the product remains fit for consumption. The research was conducted using an Air Blast Freezer refrigeration system with a TXV type expansion device (thermostatic expansion valve) and a capillary tube type, the Air Blast Freezer system is very effective in reducing product storage temperatures quickly. The purpose of the study was to compare the performance of the Air Blast Freezer system using TXV and Capillary Pipes by varying the fan rotation speed.

Boby Wisely Ziliwu et al. [3] stated that a refrigeration system with a cooling power of 30 kW was able to cool 3.5 tons (3,500 kg) of fish, with a cooling load of 1 ABF (air blast freezer) room of 28.54 kW. COPactual refrigeration engine 2.8 and COPcarnot 6.1.

Cecep Sunardi et al. [4] conducted a study using an air blast freezer refrigeration system for freezing chicken meat, a refrigeration system using TXV has a faster chilling time than using a capillary tube. The actual COP and COPcarnot values when using TXV are 2.63 and 3.71, and the efficiency value is 70.82%. While the actual COP and COPcarnot values using a capillary tube are 2.53 and 3.70 and the efficiency value is 68.38%.

Kusnandar et al. [5] compared the performance of a 1 pk Split AC using R410a and R32 refrigerants by varying the rotation of the evaporator fan (low mode, medium mode, and high mode), with the air flow speed of each mode being 1.2 m/s, 1.5 m/s and 1.9 m/s. From the results of calculations using refrigerant R410a obtained COP value of 8.13 and using refrigerant R32 obtained COP value of 5.3. The efficiency of the system using R410a is 72.8% and using R32 is 70.67%.

Markus and Tandi [6] conducted a study using an air blast freezer refrigeration system for freezing 3 kg of beef to a temperature of -12 °C, and by varying the rotation frequency of the evaporator fan at 30 Hz, 35 Hz, 40 Hz, 45 Hz, and 50 Hz. At a frequency of 50 Hz and using TXV, the chilling time is 70 minutes, while using a capillary tube, the chilling time is 46 minutes.

M. Almaududi [7] tested the performance of the refrigeration system by increasing the air flow rate entering the evaporator. An increase in the air flow rate will affect the temperature changes in the evaporator and condenser, or there will be an increase in the COP value along with the rapid heat exchange which will increase the cooling effect index.

Rojeena Shrestha and Huma Bokkhim [8] conducted an assessment of the microbial quality, physical, and sensory evaluation of Pangasius fish fillets. By using the air blast freezer refrigeration system, the microbial content decreased drastically when stored in frozen conditions.

Sukarman et al. [9] tested the performance of a vapor compression refrigeration engine using a video cassette recorder or VCR (Video Cassette Recorder). By varying the evaporator fan at five rpm levels, using a compressor with a capacity of 365 watts with refrigerant working fluid R410 as an alternative (alternative) R22. The experimental results show that the highest COP is obtained at the lowest rpm with a

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value of 3.17. While the lowest COP is 3.02 at the highest rpm.

Yohanes Viva Servianus et al. [12] presents a theoretical performance study using R290 and R600a instead of R404A and R507A, the theoretical performance of the system is based on variations in the evaporation temperature using CoolPack software with the condensation temperature held constant. The results show that at the minimum evaporator temperature, the performance of the system using R290 and R600a is on average ±14% higher than that of R404A and R507A.

II. LITERATURE REVIEW

Air blast freezer or air blast freezing is a fast freezing process by blasting cold/frozen air to below its freezing temperature. The air is blown vigorously using a fan and in direct contact with the evaporator coil until the air temperature becomes cold. High velocity cold/frozen air will come into contact with the frozen product resulting in rapid heat transfer by convection.

The cooling system in the refrigerator is adequate, but the cooling process takes a long time, so there is still the possibility of damage to the product. In the Air Blast Freezer system, beef is frozen quickly until it reaches a temperature of -12 C or even lower, to achieve this condition it must be noted how ice crystals in beef are formed, the formation of ice crystals in beef greatly affects the quality of beef that is produced [13]. Furthermore, the ice crystals will undergo a process of freezing into ice, this stage is known as the thermal arrest period. When about 55% of the water has turned to ice, the temperature will drop more rapidly, and during this third stage most of the water turns to frozen. During this third stage, the heat that must be released is relatively small, so the time needed to lower the temperature is also relatively shorter.

The performance of the refrigerant as a working fluid is shown in the form of a pressure diagram (P) against enthalpy (h). The following is a diagram of the pressure to enthalpy in the vapor compression refrigeration cycle.

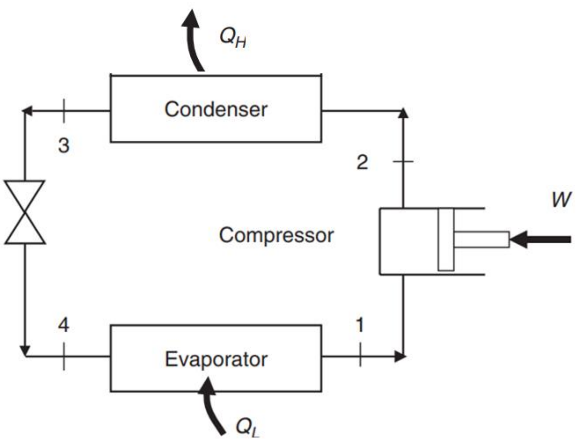

Figure 1. Vapor-compression refrigeration system

Low pressure refrigerant vapor that enters at the suction side (suction) is pressed inside the compressor so that it turns into high pressure refrigerant vapor which is released at the exit side (discharge). Assuming the work of compression is adiabatic, the heat entering the compressor per unit mass is:

$$Q_k = (h_2 - h_1)$$

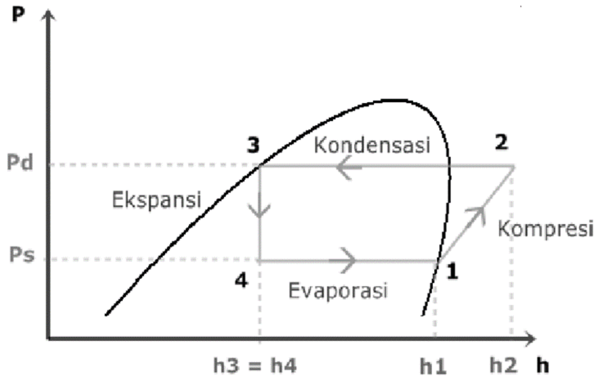

Figure 2. Pressure diagram (P) enthalpy (h) of vapor compression refrigeration system

From the discharge side of the compressor, high pressure and high temperature refrigerant vapor enters the condenser, the refrigerant undergoes a condensation process and releases heat to the cooling medium until all of the refrigerant turns into a liquid. The heat energy released in the condenser per unit mass is:

$$Q_c = (h_2 - h_3)$$

High-pressure liquid refrigerant from the condenser enters the expansion valve (can be a thermal expansion valve or capillary tube) and experiences throttling, the refrigerant experiences a decrease in temperature and pressure which results in:

$$h_3 = h_4$$

Low pressure and low temperature refrigerant from the expansion valve enters the evaporator, the refrigerant evaporates and takes heat from the environmental medium (product) until all the refrigerant turns into vapor. The heat energy absorbed in the evaporator per unit mass is:

$$Qe = (h_1 - h_4)$$

The rate of heat absorbed by the evaporator is known as the refrigeration effect. The input power to the refrigeration system is the same as the input power to drive the compressor so that the performance of the refrigeration system is expressed as the ratio between the refrigeration effect and the compressor input power, and is expressed as COP (Coefficient of Performance):

$$COP_{actual} \frac{Energi\ diserap\ di\ evaporator\ (Qe)}{Kerja\ kompresor\ (w)}$$

The performance of an ideal refrigeration system works based on the COP_{carnot} cycle, and COP_{carnot} is expressed as the ratio between the absolute evaporation temperature and the difference between the absolute condensing temperature and the absolute evaporation temperature, namely:

$$COPcarnot = \frac{Tevaporasi}{(Tkondensasi - Tevaporasi)}$$

The efficiency of the refrigeration system is expressed as the ratio between COP_{actual} and COP_{carnot}, namely:

$$\mu_{ref} = \frac{COP_{actual}}{COP_{carnot}} x\ 100\%$$

III. RESEARCH METHODS

Methods The research was conducted by modifying a single-door refrigerator (cool box), and the research was carried out in the laboratory of the Department of Refrigeration and Air Conditioning Engineering at the Bandung State Polytechnic. The main parts that have been modified include:

a. Adding a TXV (thermal expansion valve) expansion device
b. Installing an inverter to change the frequency of the evaporator fan
c. Replacing and adjusting the length of the capillary tube for a 1/2 pk compressor

The quantities measured are temperature, pressure, product freezing time by varying the frequency of the evaporator fan. The following is a schematic and measurement points on the research tool.

1. Discharge pressure
2. Suction pressure
3. Temperature discharge
4. Temperature suction
5. Condensation temperature
6. Expansion temperature
7. Evaporation temperature
8. Cabin temperature
9. Product temperature

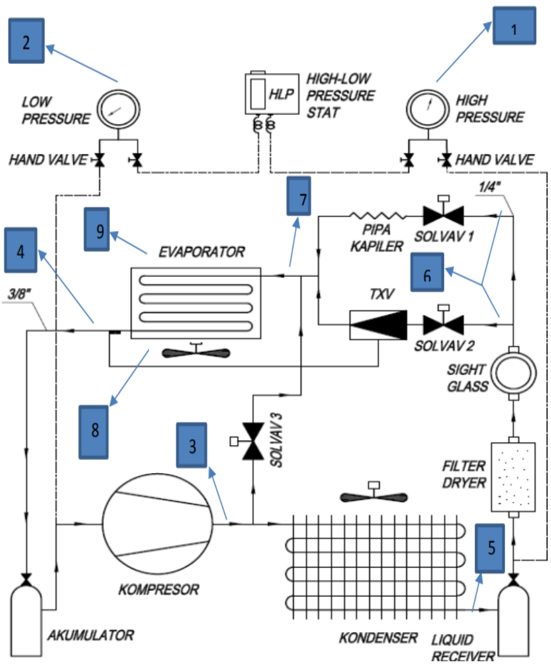

Figure 3. System piping diagram with measuring points

IV. RESULTS AND ANALYSIS

4.1. Refrigeration effect

Figure 4 is a graph of the average value of the refrigeration effect when the system steady for each variation of the rotation of the evaporator fan using TXV and capillary tube. The graph above shows that the highest average value of the refrigeration effect when the steady system using TXV reaches 169.3 kJ/kg, namely in variation-5, while the lowest average refrigeration effect value when the system is steady using TXV reaches 167.9 kJ/kg that is in variation-3. When the steady system uses a capillary tube, the highest average refrigeration effect value reaches 168.0 kJ/kg, namely in variation-4, while the lowest average refrigeration effect value when the steady system uses a capillary tube reaches 165.5 kJ/kg, namely on variation-2. From these data, if the average is calculated when the system is steady, the value of the refrigeration effect when using a capillary tube is lower than when using TXV. And from the graph, it can be seen that when the fan rotation speed is getting slower, the value of the refrigeration effect tends to be higher.

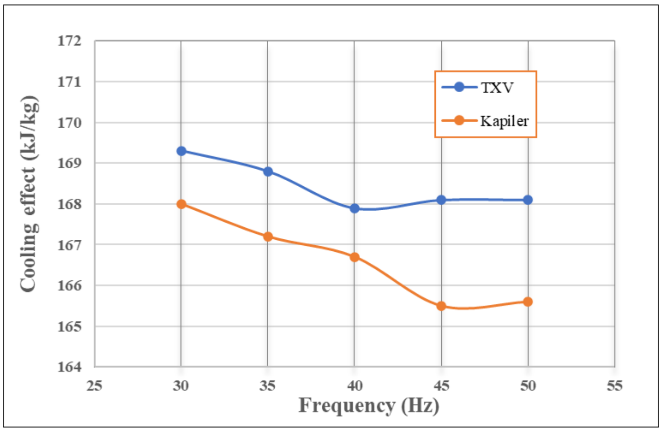

Figure 4. Cooling effect curve

4.2. Compressor specific work

Figure 5 is a graph of the average compression work value when the system is steady against each variation of the evaporator fan rotation using TXV and a capillary tube. The graph above shows that the highest average compression work value when the steady system uses TXV reaches 38.3 kJ/kg, namely in variation-3, while the average compression work value is 38.29 kJ/kg the lowest when the steady system using TXV reached 36.2 kJ/kg, namely in variation-2.

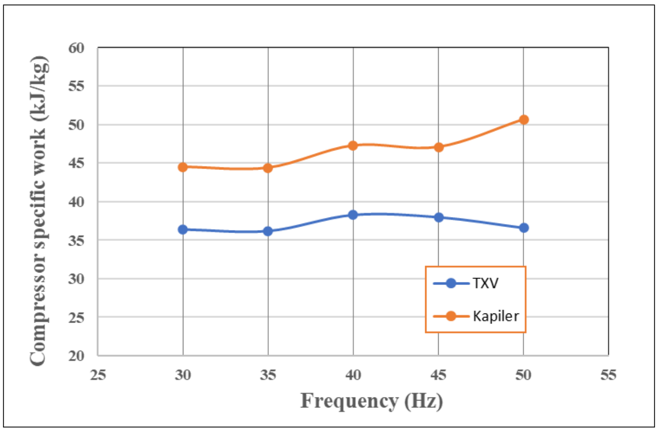

Figure 5. Compressor specific work curve

When the steady system uses a capillary tube, the highest average compression work value reaches 50.7 kJ/kg, namely in variation-1, while the lowest average compression work value when the steady system uses a capillary tube reaches

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44.4 kJ/kg, namely on variation-4. From these data, it is calculated on an average when the system is steady, the compression work value when using a capillary tube is higher than when using TXV. And from the graph, it can be seen that when the fan rotation speed is getting slower, the compression work value tends to be lower.

4.3. Actual performance coefficient

Figure 6 describes the graph of the average actual COP value when the system is steady against variations in fan rotation speed using TXV and capillary pipes. When using TXV the highest average actual COP value when the steady system reached 4.7 in variation-5, and the lowest reached 4.4 in variation-3. Meanwhile, when using a capillary tube, the highest average actual COP value when the steady system reached 3.8 in variation-4, and the lowest reached 3.3 in variation-1. When compared, the actual COP value using TXV is higher than when using a capillary tube. From the data for each variation, changes in the actual COP value from when the system starts to steady until the minute before the cut-off system decreases, this is because the longer the system works, the more stable the system. And after the system is cut-off, the actual COP value rises again, because the system has not returned to a steady state. The actual COP value is determined by the ratio of the refrigeration effect to the compression work.

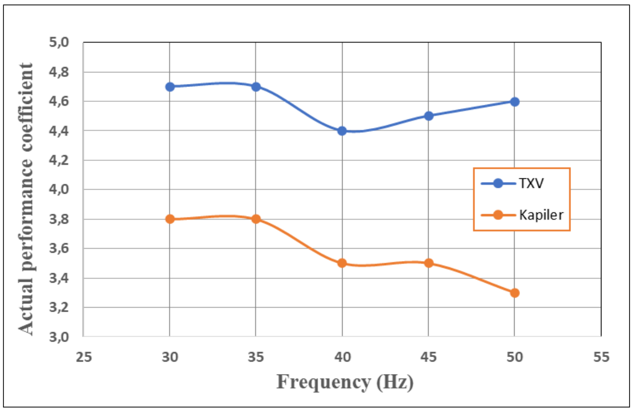

Figure 6. Actual performance coefficient curve

4.4 Efficiency

Figure 7 is a graph of the average efficiency value when the system is steady on variations in fan rotation speed. From the graph above, it can be seen that the variation of fan 1 rotation speed has the best average system efficiency when using TXV, which is 79% at steady. When using a capillary tube, the average best efficiency value when the steady system reaches 8% in variation-2. While variation-1 when using a capillary tube, the average efficiency value achieved is not as large as the variation 2, this is because the system experiences a very fast cut-off in variation-1 because the product has reached its thermostat setting temperature, namely by achievement time is 40 minutes, so the visible data is not wide enough. From these data, the capillary tube has a better system efficiency than TXV when the system is steady. Overall, the average value of system efficiency in all variations has a fairly good value of 76% - 85% at steady.

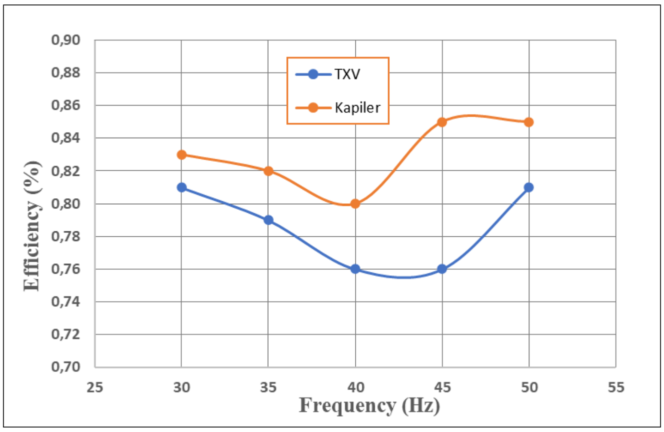

Figure 7. Efficiency curve

V. CONCLUSIONS

From the results of the analysis can be concluded:

1. The refrigeration effect using TXV is greater than using a capillary tube
2. Using a capillary tube, requires a larger compressor work than using TXV
3. The performance of the refrigeration system using TXV is better than using a capillary tube
4. However, the efficiency of the refrigeration system using a capillary tube is better than using TXV

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