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EXPERIMENTAL STUDY OF THE EFFECT OF EVAPORATOR TEMPERATURE ON VARIATIONS IN CAPILLARY TUBE LENGTH IN A REFRIGERATOR TEST APPARATUS

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Abstract
This study aims to determine the effect of capillary tube length on the temperature and pressure of the evaporator as well as the performance of the refrigeration system using R134a refrigerant. Three variations of capillary tube lengths were used: 900 mm, 1100 mm, and 1300 mm, with a diameter of 0.070 inches. The experimental method was conducted using a refrigeration system and heat pump with measurements of discharge pressure, suction pressure, condenser temperature, evaporator temperature, and compressor current. The results show that the 900 mm capillary tube produces the highest pressure (108 Psi) but the lowest COP (3.32), while the 1100 mm capillary tube produces the highest COP of 3.50. This study contributes to the optimization of small-scale refrigeration system design and provides empirical understanding of the effect of capillary tube geometry on system performance.

Keywords: Refrigerasi, Pipa Kapiler, Efek Temperatur, COP, R134a

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INTRODUCTION

Refrigeration and heat pump systems are essential components of modern energy conversion technology and play a significant role in both industrial and household applications.(et al., 2014) These systems are used in food cooling, air conditioning, and efficient temperature control through heat transfer processes between high and low-temperature environments.(Albaali & Farid, 2006) With the advancement of technology and the demand for energy efficiency, innovations in refrigeration system design have become crucial to enhance efficiency and reduce environmental impact caused by the use of conventional energy and refrigerants.(Shukla et al., 2018) (Kitanovski, 2015)

Various studies have been conducted to improve the performance of refrigeration systems by varying components and types of refrigerants.(Satsangi et al., 2008) analyzed a heat pump system integrated into a household air conditioner and found that increased drying load reduced energy efficiency.(Patil & Patil, 2013) studied a solar-assisted heat pump system using HFC-134a and reported an increase in COP values with the increasing volume of the water reservoir.(Sivaramakrishnaiah et al., 2024) However, the direct relationship between capillary tube dimensions and evaporator temperature characteristics has rarely been studied experimentally, particularly in laboratory-scale systems using R134a refrigerant.(Nadjib & Santosa, 2022) The primary function of the capillary tube is as an expansion device that affects the refrigerant flow rate and pressure drop within the system.(Sazanskyi & Khmelniuk, 2023) Variations in the length of the capillary tube can cause significant changes in the pressure and temperature of the evaporator, which in turn impacts the COP value and efficiency of the cooling system.(et al., 2025) (Mahmood et al., 2021)Therefore, this study is important to determine the optimal configuration that results in the best performance for small-scale refrigeration systems.(Ersoy & Bilir Sag, 2014)

METHODS

This study uses a quantitative experimental method to analyze the effect of capillary tube length variations on the performance of a refrigeration system. The research was conducted at the Mechanical Engineering Laboratory, Pejuang Republik Indonesia University, Makassar, during the period of September–December 2023. The test apparatus consisted of a vapor compression refrigeration system with three variations of capillary tube lengths: 900 mm, 1100 mm, and 1300 mm, with a fixed diameter of 0.070 inches. The refrigerant used was R134a. Parameters measured included discharge and suction pressures, condenser and evaporator temperatures, as well as the compressor current. The COP value was calculated based on the ratio between the cooling effect and the compressor work. All tests were conducted under relatively constant environmental conditions to maintain the accuracy of the results.

RESULTS AND DISCUSSION

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The results of the study indicate that capillary tube length significantly affects the pressure, evaporator temperature, and the performance of the cooling system. For the 900 mm capillary tube, the discharge pressure reached 108 Psi (≈ 845.99 kPa) and the suction pressure was 4 Psi (≈ 128.91 kPa). The evaporator temperature was recorded at –10 °C, with the heat pump temperature at 62 °C, but the COP value was only 3.32. For the 1100 mm capillary tube, the discharge pressure decreased to 95 Psi (≈ 756.35 kPa) and the suction pressure to 1.8 Psi (≈ 113.74 kPa), with an evaporator temperature of –13 °C and a heat pump temperature of 56 °C. The COP value increased to 3.50, indicating better efficiency.

Table 1. Effect of Capillary Tube Length on Condenser Pressure Changes

CT	Condenser Pressure	Condenser Temperature	Compressor Work	Heat Pump Effect	COP
mm	kPa	^{0}C	kJ/kg	kJ/kg	
900	845,99	62	60,12	199,72	3,32
1100	756,35	56	57,33	200,87	3,50
1300	845,99	58	57,64	195,64	3,39

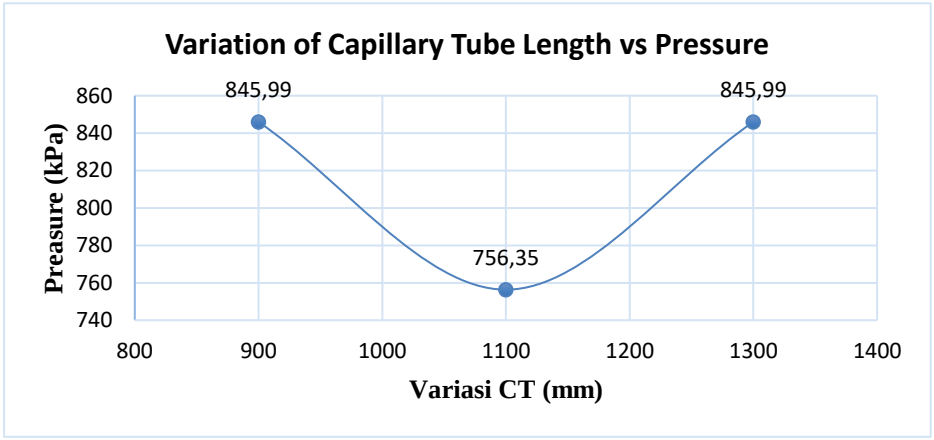

Figure 1. Capillary Tube Length Variation vs Pressure Graph

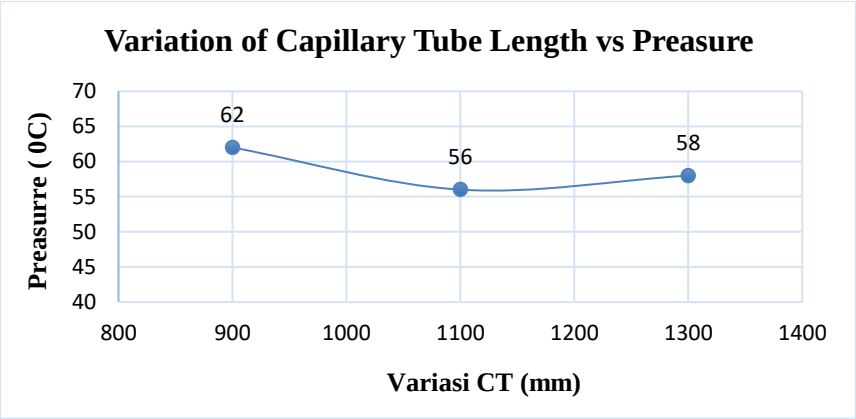

Figure 2. Capillary Tube Length Variation vs Pressure Graph

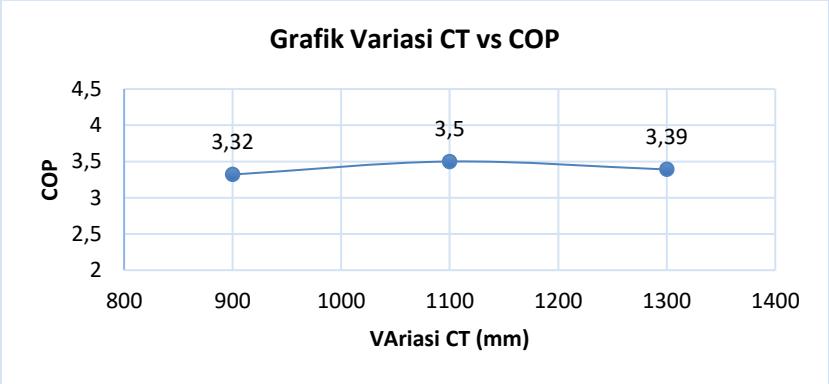

Figure 3. Capillary Tube Length (CT) Variation vs COP Graph

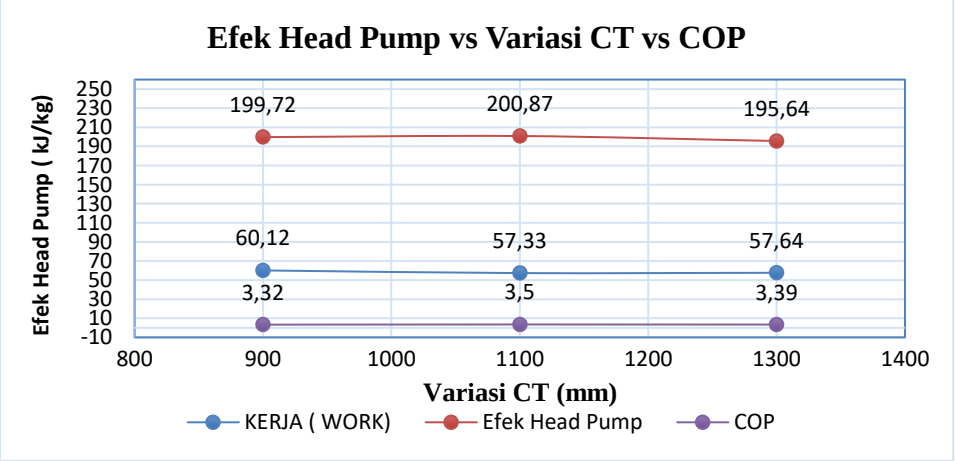

Figure 4. Heat Pump Effect vs Capillary Tube Length Variation on COP Graph

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CONCLUSION

This study experimentally examines the effect of capillary tube length variations on the temperature, pressure, and performance of an R134a-based refrigeration system. The shortest capillary tube (900 mm) resulted in the highest pressure but the lowest efficiency, while the 1100 mm capillary tube provided the best performance with a COP of 3.50. This study reinforces the theory regarding the relationship between throttling effects and refrigerant mass flow rate in the vapor compression cycle and can serve as a reference for designing energy-efficient cooling systems.

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