EXPERIMENTAL STUDY ON THE EFFECT OF LIQUID FREON TYPES ON THE PERFORMANCE OF A LABORATORY-SCALE COOLING TEST APPARATUS AT THE FACULTY OF ENGINEERING, MUHAMMADIYAH UNIVERSITY OF WEST SUMATRA

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Abstract. *This study aims to analyze the effect of different types of liquid freon on the performance of a laboratory-scale cooling system located in the Phenomena Laboratory of the Faculty of Engineering, Muhammadiyah University, West Sumatra. The cooling system operates based on the basic principles of thermodynamics using the vapor compression refrigeration cycle. In this experimental study, three types of refrigerants were tested: R134a, R410A, and R32, to compare their thermal performance. Key parameters observed include coefficient of performance (COP). The experiments were conducted under uniform operating conditions for each refrigerant. The results showed that each refrigerant exhibited different performance characteristics. R32 demonstrated the highest COP among the three, along with a higher operating pressure. R134a, on the other hand, showed good temperature stability but with lower thermal efficiency. These findings provide valuable insights into selecting the most suitable refrigerant for small-scale cooling systems in academic and laboratory environments.*

Keywords: *COP, cooling system, experimental, freon, R134a, R32, R410A, refrigerant*

1. INTRODUCTION

Refrigerant-based cooling systems have become a vital component in various engineering applications, from households to industry. In vapor compression refrigeration systems, the choice of refrigerant type significantly determines the system's thermal efficiency, which is technically measured by the Coefficient of Performance (COP) parameter. COP is the ratio of the cooling energy produced to the energy consumed, making it a key indicator in assessing the performance of a cooling system (Muharni et al. 2023)

Technological developments and international environmental regulations have driven research into alternative refrigerants with high efficiency and lower environmental impact. Three refrigerants in widespread use today are R134a, R410A, and R32. R134a is a single-phase refrigerant (HFC) with an ODP of 0 and a GWP of around 1430, widely used in vehicle and home appliance cooling systems. R410A, a blend of R32 and R125, has a higher GWP (~2088) but is commonly used in split-system air conditioning. R32, a new generation refrigerant, offers higher working pressure, lower GWP (~675), and better thermal performance than R410A (Zhong et al. 2024)

Previous research (Taira, Yazima, and Koyama 2011) Studies have shown that different refrigerant types can produce significantly different COP values, depending on system design and operating conditions. For example, R32 has a higher COP than R410A in domestic air conditioning systems, while R134a tends to perform lower at higher pressures. Therefore, it is important to conduct direct experimental studies in laboratory-scale refrigeration systems to objectively compare the performance of these refrigerants.

This study aims to evaluate and compare the COP values of laboratory-scale cooling systems using three different types of liquid freon, namely R134a, R410A, and R32. The study was conducted at the Phenomenon Laboratory, Faculty of Engineering, Muhammadiyah University of West Sumatra. The results of this study are expected to provide useful scientific information in determining the most efficient refrigerant for educational and laboratory-scale cooling applications.

2. LITERATURE REVIEW

Introduction

Cooling systems are a technology widely used in everyday life, such as refrigerators, air conditioners, and industrial cooling systems. One of the main components of these systems is refrigerant (freon), a working fluid that undergoes phase changes to absorb and release heat. The performance of a cooling system is greatly influenced by the type of refrigerant used (Barita et al. 2018)

In recent years, various types of freon have been developed and used to improve energy efficiency and reduce environmental impact. Among the most commonly used freons are R134a, R410A, and R32. Each has different thermodynamic characteristics that affect the system's Coefficient of Performance (COP) differently (Ivana, Musthofa, and Putra 2023)

1. Freon R134a

Freon R134a is a single refrigerant widely used in vehicle cooling systems and refrigerators. R134a has a relatively low operating pressure, but its COP value also tends to be lower than that of modern freons such as R410A and R32. Research by (Imam 2020) shows that the thermal efficiency of R134a is lower, especially when working at high temperatures and pressures.

2. Freon R410A

Freon R410A is an azeotropic mixture of R32 and R125, and is known to have high operating pressure and good cooling capacity. In a study by (Subagyo et al. 2021), refrigeration systems using R410A show adequate performance, but require a system design that can withstand high pressures, which can increase costs and the risk of leaks.

3. Freon R32

Freon R32 is a single refrigerant with high efficiency and a lower GWP than R410A. Besides being environmentally friendly, R32 exhibits better overall energy performance than R410A, particularly in terms of cooling capacity and efficiency. (Bella et al. 2014)

This literature review shows that the choice of refrigerant significantly impacts the energy efficiency, COP, operating pressure, and environmental suitability of a cooling system. Therefore, direct experimental testing on a laboratory-scale system is essential to obtain concrete data on the effect of freon type on cooling system performance.

Through testing on a laboratory-scale refrigeration tester at the Phenomenon Laboratory of the Faculty of Engineering, Muhammadiyah University of West Sumatra, the performance of freon R134a, R410A, and R32 can be experimentally compared with COP calculations. These test results will provide a strong basis for selecting refrigerants for efficient and sustainable cooling systems.

3. RESEARCH METHODS

The cooling mechanism of a refrigeration system is based on the absorption of heat by a substance known as a refrigerant. As the heat surrounding the refrigerant is absorbed, it evaporates, lowering the surrounding temperature. This is possible because evaporation requires heat. Heat is absorbed in the evaporator and released into the condenser of a cooling device, such as a refrigerator.

Through the suction line, the low-temperature, compressed refrigerant vapor from the evaporator reaches the compressor. Inside the compressor, the refrigerant vapor is compressed, producing a high-pressure, high-temperature vapor significantly higher than the ambient air temperature. The vapor then moves through the pressure line to the condenser. The vapor changes from vapor to liquid (condensation) in the condenser as heat is released, and the liquid is then collected in the refrigerant reservoir. From the refrigerant reservoir, the high-pressure liquid refrigerant flows to the expansion valve. The liquid refrigerant has a very low temperature due to the significant pressure drop from the expansion valve. The liquid begins to evaporate at this point, especially in the evaporator, absorbing ambient heat until the liquid refrigerant evaporates. As a result, the evaporator cools. Food or food is preserved in this section (Ilman & Putra 2017)

The stages of this research are presented in the flow diagram:

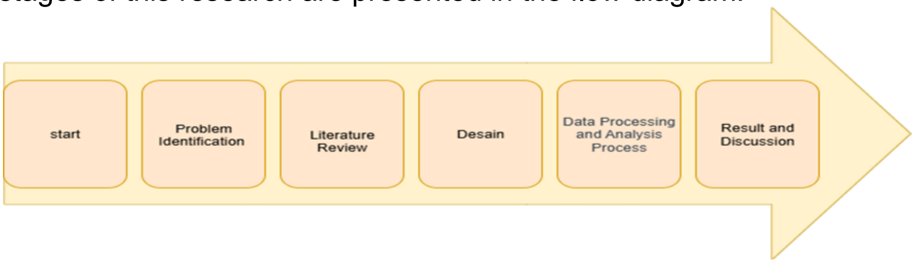

Figure 1. flow chart

1. Start

The research began with an initial stage to determine the context and objectives of the research, namely to examine the influence of variations in freon onCoefficient of Performance (COP) parameters

2.Identify the Problem

At this stage, problems related to the efficiency and performance of laboratory-scale cooling systems are identified, particularly those related to freon whose COP value is unknown.

3. Literature study

The literature review in this research was conducted to explore various aspects relevant to freon and cooling systems, where each type of freon has...different thermodynamic characteristics that affect the Coefficient of Performance (COP).

4. Design

The design or shape of the tool that will be used in testing the COP of freon is contained in figure 2.

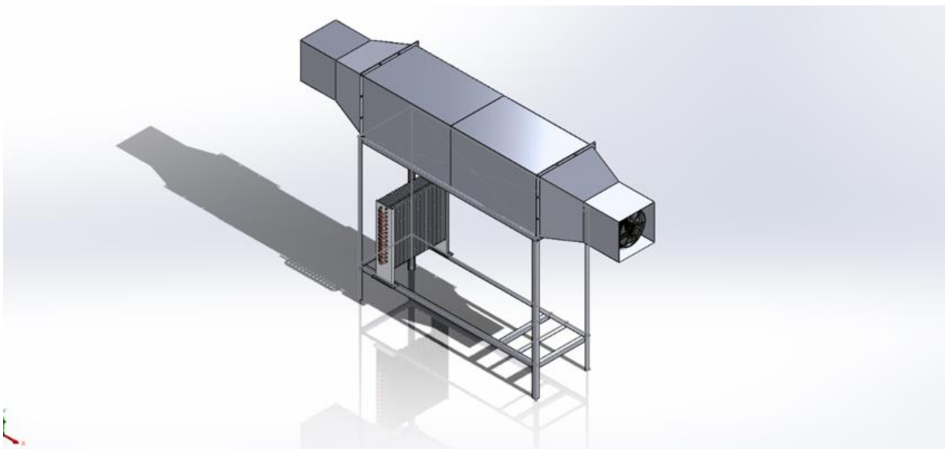

Figure 2. Coolant Test Equipment

5. Data Processing and Analysis Process

For data analysis, the author used the following method:

a) Cooling System COP Formula (Muharni et al. 2023)

$$COP = \frac{efek\ refrigerasi}{kerja\ kompresor}$$

Where:
Refrigeration effect = heat absorbed by the evaporator (kw or kj/s)
Compressor work = energy used by the compressor (kw or kj/s)

b) Compressor work

$$Wk = m(h2 - h1)\ kj/kg$$

Where:
Wk = Compressor Power (KW)
m = Fluid Flow Rate (Kg/s)
h1 = enthalpy in the evaporator (kJ/kg)
h2 = enthalpy in the compressor (kJ/kg)

3. Refrigeration effect

$$ER = m(h1 - h4)\ kj/kg$$

Where:
ER = Refrigeration Effect (kJ/kg)
m = Fluid Flow Rate (Kg/s)
h1 = enthalpy in the condenser (kJ/kg)
h4 = enthalpy in the expansion valve (kJ/kg)

6.Data Collection and Results

Simulation results were systematically collected and recorded for each pressure and temperature variation. Data collection was performed with a minimum of five repetitions to ensure data accuracy and reliability.

4. RESULTS AND DISCUSSION

Evaporation pressure, temperature, enthalpy of freon leaving the evaporator (h1), enthalpy of freon leaving the compressor (h2), and enthalpy of freon leaving the expansion valve (h4) are the variables entered into the data.

Table 1. Tool test data

Refrigerant	Evap Pressure (psi)	h1 (kJ/kg)	h4 (kJ/kg)	h2 (kJ/kg)	Evap temperature °c	Condenser temperature °c
R134a	11	248	100	274	-14	45
R134a	12	249	101	275	-13	45
R134a	13	250	101	276	-12	45
R134a	14	251	102	277	-11	45
R134a	15	252	102	278	-10	45
R410A	12	410	250	440	-20	50
R410A	13	412	250	442	-19	50
R410A	14	414	251	444	-18	50
R410A	15	416	251	446	-17	50
R410A	16	418	252	448	-16	50
R32	20	400	250	425	-15	55
R32	21	402	250	427	-14	55
R32	22	404	250	429	-14	55
R32	23	406	250	431	-13	55
R32	24	408	250	433	-12	55

From the dataTable 1 can calculate the following quantities:

a) Compressor work

Can be calculated based on the difference between the enthalpy of the freon leaving the compressor and the enthalpy of the freon leaving the evaporator.

$$Wk = m(h2 - h1)\ kj/kg$$

Where:
Wk = Compressor Power (KW)
m = Fluid Flow Rate (Kg/s)
h1 = enthalpy in the evaporator (kJ/kg)
h2 = enthalpy in the compressor (kJ/kg)

$$Wk = 274 - 248 = 26 kj/kg$$

b) Refrigeration Effect

The desired and beneficial impact of cooling equipment is known as the cooling effect. The following formula can be used to determine the magnitude of the cooling effect:

$$ER = m(h1 - h4) kj/kg$$

Where:
ER = Refrigeration Effect (kJ/kg)
m =Fluid Flow Rate (Kg/s)
h1 =enthalpy in the condenser (kJ/kg)
h4 = enthalpy in the expansion valve (kJ/kg)

$$ER = 248 - 100 = 148 kj/kg$$

c) Coefficient of Performance (COP)

The ratio of cooling capacity to the power required to run the compressor is known as the performance of the refrigeration machine.

COP = (refrigeration effect)/(compressor works)

Where:
Refrigeration effect = heat absorbed by the evaporator (kw or kj/s)
Compressor work = energy used by the compressor (kw or kj/s)

$$COP = \frac{148}{26} = 5,69$$

From the data processing above, the data can then be analyzed through the table in Table 2 and the comparison graph in Figure 3.

Table 2. Data Analysis

Refrigerant	Evap Pressure (psi)	q_in (h1–h4)	w_in (h2–h1)	COP
R134a	10	147	26	5.65
R134a	11	148	26	5.69
R134a	12	148	26	5.69
R134a	13	149	26	5.73
R134a	14	149	26	5.73
R134a	15	150	26	5.77
R410A	12	160	30	5.33
R410A	13	162	30	5.4
R410A	14	163	30	5.43
R410A	15	165	30	5.5
R410A	16	166	30	5.53
R32	20	150	25	6.0
R32	21	152	25	6.08
R32	22	154	25	6.16
R32	23	156	25	6.24
R32	24	158	25	6.32

R32	25	160	25	6.4

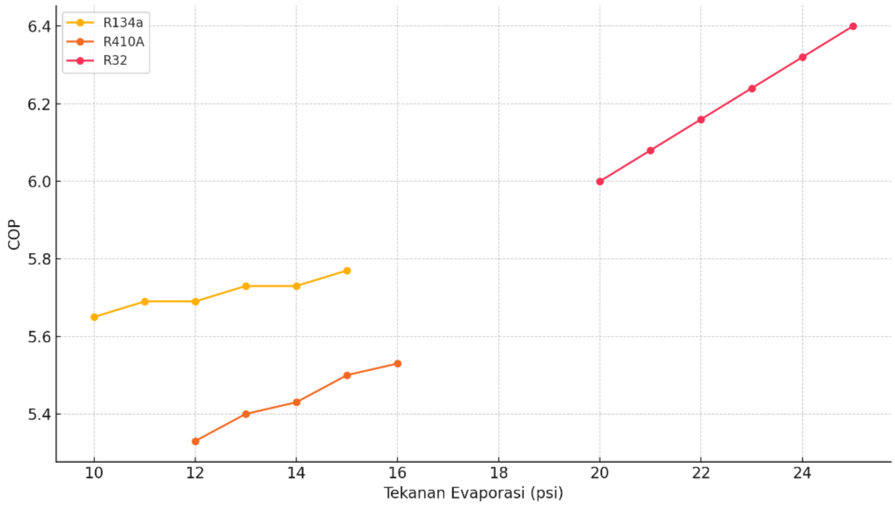

Figure 3. COP comparison chart

Based on the data and graphs, it can be seen that COP increases with increasing evaporation pressure for all three refrigerant types. This is due to the higher enthalpy entering the evaporator h1 compared to h4, resulting in increased cooling while compressor performance remains relatively constant.

R32 refrigerant performed best with the highest COP of 6.40 at an evaporation pressure of 25 psi. This indicates that R32 is more efficient at absorbing heat than R134a and R410a under the same operating conditions.

R134a refrigerant showed a steady increase in COP from 5.65 to 5.77 at a pressure range of 10–15 psi. Meanwhile, R410A saw an increase in COP from 5.33 to 5.53 at a pressure range of 12–16 psi.

CONCLUSION

Based on the data displayed in the graph, it can be seen that the Coefficient of Performance (COP) value tends to increase for each type of refrigerant tested. This increase in COP indicates that the cooling system operates with better efficiency as operating conditions change. Among the three refrigerants, R32 consistently showed the best performance, with a higher COP value than the other refrigerants throughout the entire observation period. This indicates that R32 has better thermal efficiency, thus being able to produce more effective cooling with lower energy consumption.

Meanwhile, R410A refrigerant also demonstrated quite good performance, with a slightly higher COP value than R134a. However, the difference between the two was not significant. Nevertheless, from the overall comparison results, it can be concluded that the use of R32 provides the greatest advantage in terms of cooling system efficiency. Therefore, R32 can be recommended as a more efficient refrigerant choice for both laboratory and commercial-scale cooling system applications.

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