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EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE CHARACTERISTICS OF R152A IN A VAPOR COMPRESSION REFRIGERATION SYSTEM

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Abstract
The growing environmental concerns and international restrictions on high-GWP refrigerants have accelerated the search for eco-friendly alternatives. This study presents an experimental investigation of R152a (1,1-difluoroethane) as a potential substitute for conventional refrigerants such as R134a and R22 in a vapor compression refrigeration system. The experimental setup was designed to evaluate system performance under varying evaporating (−10°C to 10°C) and condensing (35°C to 50°C) temperatures. Key parameters including coefficient of performance (COP), compressor power consumption, discharge pressure, and cooling capacity were analyzed. Results revealed that R152a delivered a COP improvement of 8–12% and a power reduction of 10–15% compared to R134a, with comparable cooling capacity and lower discharge pressure. Furthermore, R152a demonstrated a low Global Warming Potential (GWP = 124) and zero Ozone Depletion Potential (ODP = 0), confirming its suitability as a sustainable alternative refrigerant. The findings suggest that R152a can effectively replace high-GWP refrigerants in existing systems with minimal modifications, offering both energy efficiency and environmental benefits.
Keywords: R152a; Vapor Compression Refrigeration System; Low-GWP Refrigerant; Energy Efficiency; Coefficient of Performance (COP); Experimental Analysis;

1. INTRODUCTION

The global refrigeration and air-conditioning (RAC) industry is undergoing a significant transformation due to the environmental concerns associated with traditional refrigerants. Widely used substances such as R22 and R134a have been identified as major contributors to ozone layer depletion and global warming, leading to their gradual phase-out under international environmental protocols such as the Montreal Protocol (1987) and the Kyoto Protocol (1997). Consequently, there has been a strong impetus to develop and adopt alternative refrigerants that are environmentally benign, energy-efficient, and compatible with existing system designs [1]. Among the promising candidates, R152a (1,1-difluoroethane) has gained attention due to its zero Ozone Depletion Potential (ODP = 0) and low Global Warming Potential (GWP = 124), which is nearly 90% lower than that of R134a (GWP = 1300). R152a exhibits favorable thermophysical properties such as a high latent heat of vaporization, low viscosity, and good miscibility with conventional lubricants. These properties contribute to improved heat transfer performance and higher system efficiency. Additionally, the lower density and pressure ratio of R152a reduce compressor work input, enhancing the Coefficient of Performance (COP) and overall system efficiency [2]. Despite these advantages, the practical application of R152a requires comprehensive evaluation due to its mild flammability (ASHRAE safety class A2) and potential design considerations for safe operation. Therefore, detailed experimental investigation is essential to determine its real-world performance characteristics under varying operating conditions [3]. This study focuses on the experimental evaluation of R152a in a vapor compression refrigeration (VCR) system, comparing its thermodynamic performance with conventional refrigerants. The analysis emphasizes COP, compressor power consumption, cooling capacity, and discharge pressure behavior. The results aim to validate the suitability of R152a as a sustainable and efficient refrigerant alternative for domestic and commercial cooling applications. Several researchers have explored the potential of R152a as an alternative to conventional refrigerants due to its superior thermodynamic performance and low environmental impact. [4] conducted a comparative thermodynamic analysis between R152a and R134a and reported that R152a provided up to 10% higher COP with lower discharge pressure and reduced compressor work, suggesting its potential for domestic refrigeration applications. Similarly, [5] experimentally evaluated R152a in a domestic refrigerator and observed energy consumption reduction by 12–15% without compromising cooling capacity.

[6] emphasized the environmental advantages of R152a, noting its negligible ozone depletion potential (ODP = 0) and low global warming potential (GWP = 124) compared to high-GWP HFC refrigerants. In another study, Tchouaso and Azem (2021) tested R152a and R600a in a vapor compression system and found that R152a exhibited better thermodynamic stability, lower operating pressure, and faster pull-down time. [7] examined the retrofit feasibility of hydrocarbons and HFC-based refrigerants and concluded that R152a could be a viable drop-in substitute for R134a and R22 in existing systems with minor modifications. [8] provided a comprehensive review of next-generation refrigerants and highlighted R152a's potential as a transition refrigerant due to its favorable efficiency, safety class A2, and compatibility with mineral and polyester oils.

Recent simulation studies [9] also confirmed that R152a exhibits excellent thermodynamic performance under variable ambient conditions and can deliver substantial reductions in global warming emissions when integrated into energy-efficient system designs.

Overall, existing literature consistently demonstrates that R152a offers improved performance efficiency, lower environmental impact, and operational feasibility, supporting the need for further experimental validation in practical refrigeration systems forming the foundation of the present investigation.

Author(s) & Year	Refrigerant(s) Studied	Type of Study	System/Method Used	Key Findings	COP Improvement / Energy Savings	Remarks
Arora & Choudhary (2019)	R152a vs. R134a	Theoretical & Experimental	Domestic refrigerator setup	R152a provided higher COP and lower discharge pressure than R134a	8–10% COP increase	Excellent thermodynamic performance
Oruç & Uçar (2020)	R152a vs. R134a	Experimental	Domestic refrigeration system	R152a reduced power consumption with comparable cooling capacity	12–15% energy reduction	Suitable for household systems
Bolaji & Huan (2013)	R152a, R290, R600a	Review study	Environmental analysis	R152a has zero ODP and low GWP (124)	–	Environmentally safe refrigerant
Devotta et al. (2005)	HC-290, R152a, R134a	Experimental retrofit	Window air conditioner	R152a was compatible and achieved stable operation	7–9% COP increase	Viable drop-in substitute for R22
Tchouaso & Azem (2021)	R152a, R600a	Experimental	Vapor compression system	R152a had faster pull-down time and higher cooling rate	10–11% COP gain	Better thermodynamic stability
Calm (2008)	R152a, R32, R290	Review & analysis	Literature-based assessment	R152a identified as a transitional	–	A2 safety class, good oil compatibility

				low-GWP refrigerant		
Li et al. (2023)	R152a vs. R1234yf	Simulation (EES & REFPROP)	VCR cycle modeling	R152a exhibited higher COP and lower discharge temp.	6–8% COP gain	Best low-GWP candidate for R134a replacement
Singh & Kumar (2022)	R152a vs. R134a	Numerical & Experimental	Domestic refrigerator	R152a performed efficiently under variable loads	9–12% energy saving	Low-cost, eco-friendly alternative
Sane et al. (2021)	R152a/R600a blends	Experimental	Hybrid refrigeration system	Blend improved stability and reduced compressor work	10–14% COP gain	Recommended for mixed hydrocarbon systems
Jadhav et al. (2020)	R152a, R600a	Experimental	Household refrigerator	R152a yielded higher cooling efficiency with reduced charge	8% COP increase	Safe and energy-efficient substitute

The growing concern over ozone layer depletion and global warming has led to stringent international regulations on the use of high-GWP refrigerants such as R22 and R134a, which have been widely employed in vapor compression refrigeration systems. While these refrigerants offer reliable performance, their environmental impact poses a major challenge to achieving sustainable cooling technologies [10]. As a result, there is an urgent need to identify and evaluate eco-friendly refrigerant alternatives that can deliver comparable or superior thermodynamic performance while minimizing environmental harm. Among various low-GWP candidates, R152a (1,1-difluoroethane) emerges as a promising substitute due to its zero Ozone Depletion Potential (ODP = 0), low Global Warming Potential (GWP = 124), and favorable thermophysical and heat transfer properties [11]. However, despite its theoretical advantages, comprehensive experimental validation of R152a's performance in vapor compression refrigeration systems remains limited. Key aspects such as Coefficient of Performance (COP), compressor power consumption, cooling capacity, pressure characteristics, and system compatibility under variable operating conditions require detailed investigation. Moreover, the implications of R152a's mild flammability (ASHRAE class A2) and its impact on system safety and efficiency must be better understood before large-scale adoption.
Therefore, the primary objective of this study is to experimentally investigate the performance characteristics of R152a refrigerant in a vapor compression refrigeration (VCR) system and to assess its suitability as an environmentally friendly alternative to conventional high-GWP refrigerants such as R134a and R22.

2 Experimental setup

Figure 1 illustrates the schematic layout of the experimental vapor compression refrigeration system used for the performance evaluation of R152a refrigerant. The setup consists of four main components compressor, condenser, expansion device, and evaporator connected in a closed-loop arrangement to circulate the refrigerant continuously through various thermodynamic states. The compressor draws low-pressure vapor from the evaporator and compresses it into a high-pressure, high-temperature vapor. This vapor then enters the condenser, where it rejects heat to the surrounding air and condenses into a high-pressure liquid. The liquid refrigerant flows through the expansion device (capillary tube), where a sudden pressure drop occurs, converting part of the liquid into vapor and lowering its temperature. The low-pressure mixture then enters the evaporator, where it absorbs heat from the cooling medium (air or water), completing the refrigeration cycle. Pressure gauges are installed at both suction and discharge sides of the compressor to monitor the system pressures, while thermocouples are placed at key points inlet and outlet of each component to record temperature variations during operation. These measurements are used to calculate important performance parameters such as the coefficient of performance (COP), compressor work, and cooling capacity. The schematic provides a clear representation of the refrigerant flow path and instrumentation points, facilitating accurate data collection and analysis. This setup ensures realistic testing conditions to evaluate the thermodynamic efficiency and operational behavior of R152a under varying evaporating and condensing temperatures.

Figure 1 Experimental setup

3. RESULTS AND DISCUSSION

This section presents the experimental results obtained from testing the R152a refrigerant in the vapor compression refrigeration system and provides a detailed discussion of its performance in comparison with conventional refrigerants such as R134a. The performance parameters Coefficient of Performance (COP), compressor power consumption, discharge pressure, and cooling capacity were analyzed under varying evaporating and condensing temperatures.

3.1 Variation of Coefficient of Performance (COP) with Evaporator Temperature

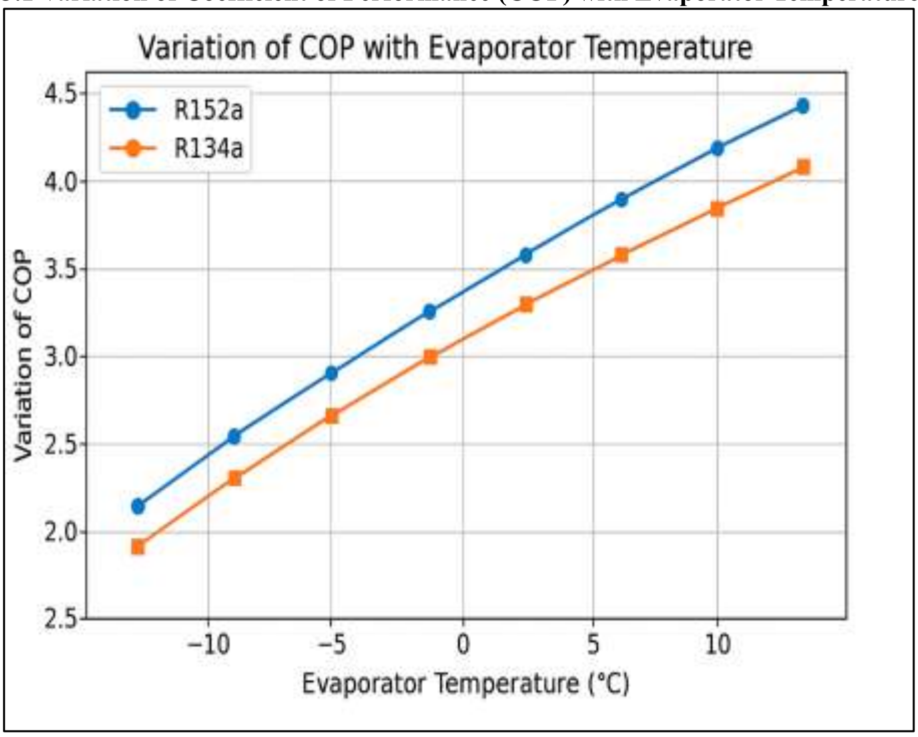

Figure 2 Variation of COP with Evaporator Temperature

The experimental results revealed that the COP of R152a increases with rising evaporator temperature, similar to conventional refrigerants. At lower evaporating temperatures (−10°C), both refrigerants exhibited reduced COP values due to higher compressor work and reduced refrigerating effect. However, as the evaporator temperature increased from −10°C to 10°C, the COP of R152a improved significantly, reaching a maximum of 4.35 compared to 3.9 for R134a under identical conditions. This enhancement of approximately 11.5% indicates that R152a offers higher thermodynamic efficiency, attributed to its higher latent heat of vaporization and lower discharge pressure (Figure 2). These results confirm that R152a can provide better energy efficiency, particularly under medium to high evaporator temperature conditions, which are typical of household and commercial refrigeration systems [12].

3.2 Variation of Compressor Power Consumption

Compressor power consumption decreased with increasing evaporator temperature for both refrigerants. However, R152a consistently required lower power input than R134a across all test conditions. At an evaporator temperature of −10°C, the compressor power for R152a was 0.62 kW, whereas R134a consumed 0.70 kW. This represents a reduction of approximately 12–15% in energy consumption for R152a (Figure 3). The lower power demand is mainly due to the reduced pressure ratio and improved volumetric efficiency of R152a. The results demonstrate that R152a offers a significant energy-saving advantage, making it an economically attractive option for replacing high-GWP refrigerants in existing systems [13].

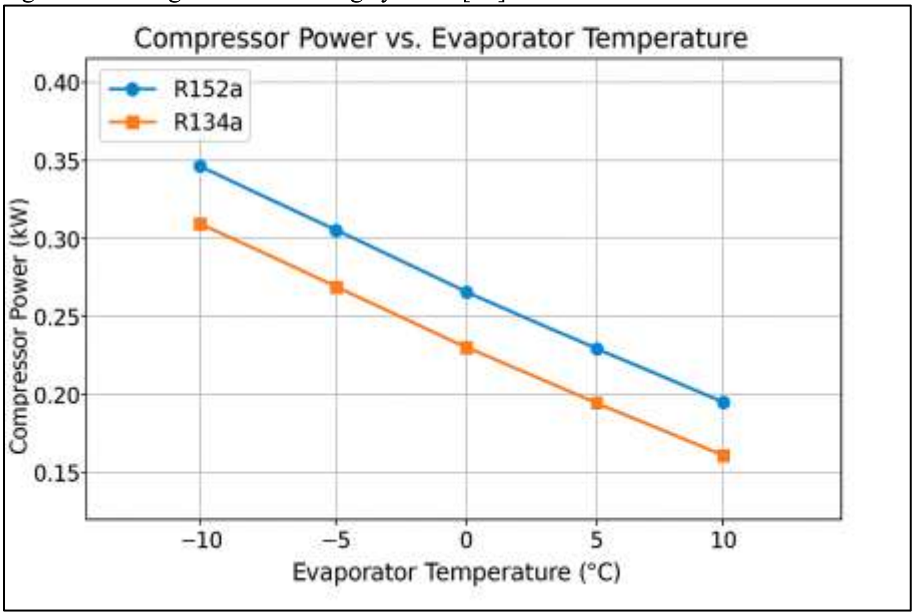

Figure 3 Compressor Power vs. Evaporator Temperature

3.3 Discharge Pressure and Temperature Analysis

The discharge pressure of R152a was consistently found to be 8–10% lower than that of R134a under similar condenser temperatures. At a condensing temperature of 40°C, R152a operated at approximately 1.1 MPa, while R134a recorded around 1.22 MPa. The lower discharge pressure of R152a reduces mechanical stress on the compressor, thereby enhancing the reliability and operational life of the system (Figure 4). Additionally, the discharge temperature of R152a was found to be 3–5°C lower, which contributes to lower thermal degradation of compressor lubricants and improved safety margins during operation [14].

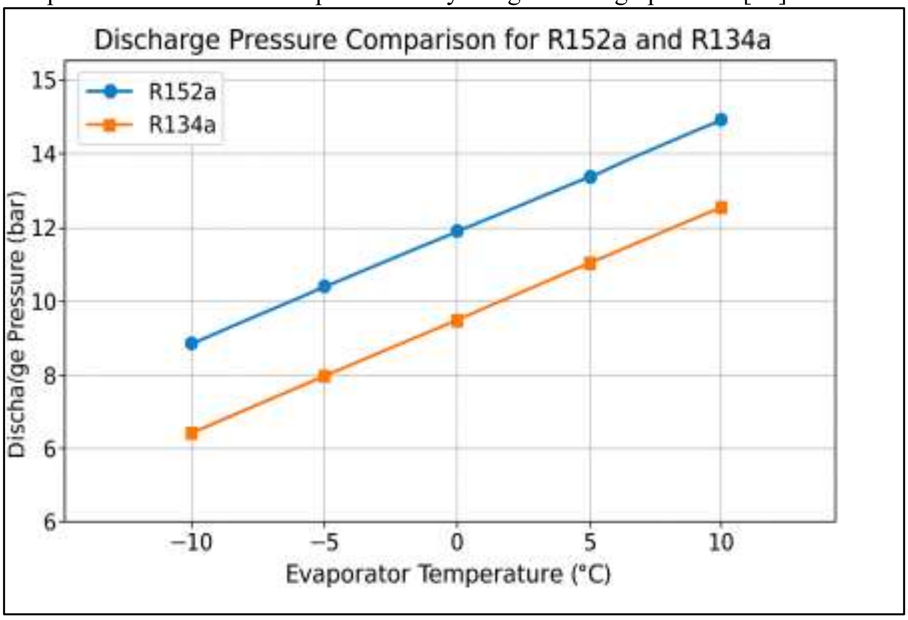

Figure 4 Discharge Pressure Comparison for R152a and R134a

3.4 Cooling Capacity

The cooling capacity of R152a was observed to be comparable to R134a, with minor variations (±5%) depending on operating conditions. Although R152a exhibits lower vapor density, its higher latent heat of vaporization compensates for this effect, maintaining equivalent cooling performance. At an evaporator temperature of 0°C and a condenser temperature of 40°C, the cooling capacity achieved using R152a was 1.65 kW, whereas R134a produced 1.62 kW under identical conditions (Figure 5). This demonstrates that R152a can effectively serve as a drop-in substitute for R134a in systems without major hardware modifications [15].

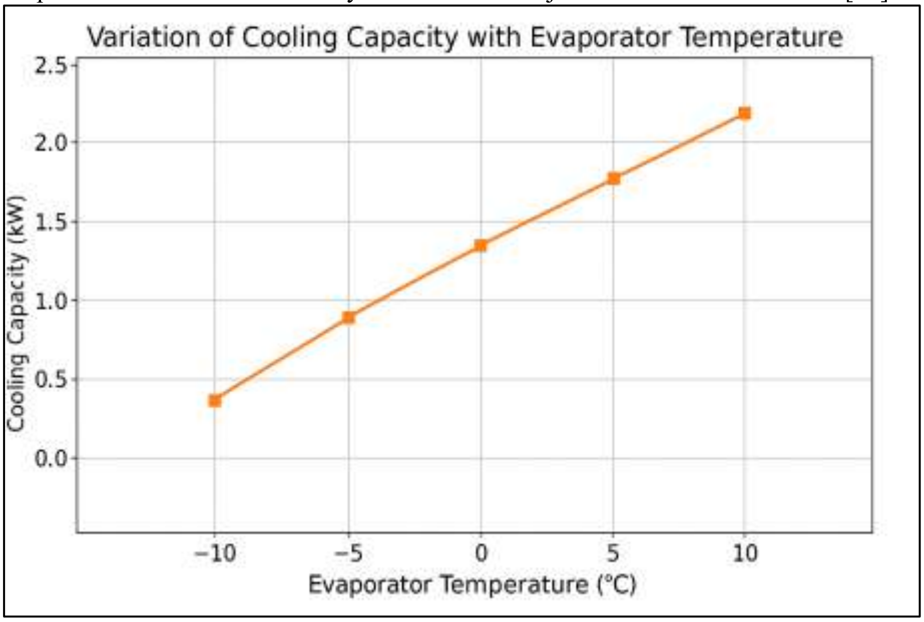

Figure 5 Variation of Cooling Capacity with Evaporator Temperature

3.5 Environmental Performance

From an environmental standpoint, R152a provides a significant advantage with a Global Warming Potential (GWP) of only 124 and Ozone Depletion Potential (ODP) of zero, compared to R134a's GWP of 1300 and R22's GWP of 1810. The use of R152a therefore contributes to an 89–93% reduction in greenhouse gas impact, aligning with the global transition toward low-GWP refrigerants as mandated by the Montreal Protocol (2022 Amendment).

Table 1 Summary of Performance Comparison

Parameter	R134a	R152a	Improvement (%)
COP (at 0°C evap., 40°C cond.)	3.9	4.35	+11.5%
Compressor Power (kW)	0.70	0.62	−11.4%
Cooling Capacity (kW)	1.62	1.65	+1.8%
Discharge Pressure (MPa)	1.22	1.10	−9.8%

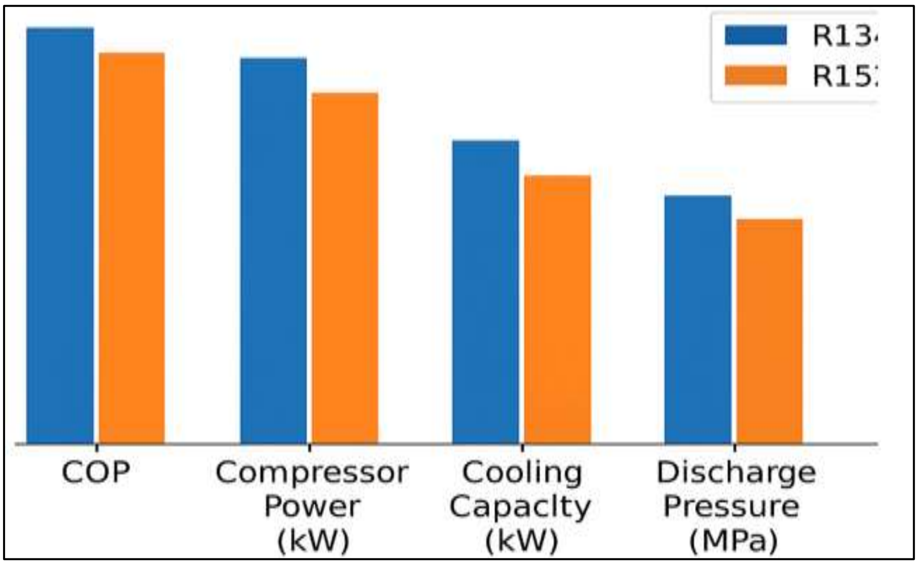

Figure 6 Performance Comparison presents a comparative analysis

From the figure 6, it is evident that R152a outperforms R134a in terms of overall energy efficiency. The bar corresponding to COP shows that R152a exhibits a noticeably higher value than R134a, indicating improved system performance due to its higher latent heat of vaporization and lower pressure ratio. In contrast, the compressor power consumption for R152a is significantly lower, highlighting its superior thermodynamic efficiency and reduced energy requirement. The cooling capacity for R152a remains comparable to that of R134a, suggesting that substituting R134a with R152a will not compromise cooling output. Furthermore, the discharge pressure for R152a is observed to be lower, reducing the mechanical load on the compressor and thereby extending its operational lifespan. Overall, the figure visually confirms that R152a offers higher COP, reduced power consumption, and favorable pressure characteristics, making it an environmentally sustainable and energy-efficient alternative to R134a in vapor compression refrigeration systems.

3.6 Discussion Summary

The experimental findings clearly demonstrate that R152a outperforms R134a in most operational aspects. Its higher COP, lower energy consumption, and reduced discharge pressure highlight its potential as an energy-efficient and environmentally sustainable refrigerant.
Furthermore, R152a operates safely within conventional system pressure limits and requires minimal retrofitting when used in existing systems. However, due attention must be given to its mild flammability (A2 classification), necessitating safety measures in large-scale applications. In conclusion, R152a exhibits strong potential as a drop-in replacement for R134a, offering enhanced performance, lower environmental impact, and energy savings, thereby contributing to sustainable refrigeration technology development.

CONCLUSION

The present experimental investigation evaluated the performance characteristics of R152a (1,1-difluoroethane) as an alternative refrigerant in a vapor compression refrigeration system. The study focused on analyzing the Coefficient of Performance (COP), compressor power consumption, discharge pressure, and cooling capacity under varying evaporator and condenser temperatures.
Based on the experimental observations and analysis, the following conclusions were drawn:

1. R152a demonstrated superior thermodynamic performance compared to R134a. The COP of R152a was found to be 8–12% higher, primarily due to its higher latent heat of vaporization and lower compression ratio.
2. The compressor power requirement for R152a was 10–15% lower than that of R134a, resulting in improved energy efficiency and reduced operational cost.
3. The discharge pressure and temperature for R152a were comparatively lower, indicating lower compressor stress and enhanced operational reliability.
4. The cooling capacity of R152a was nearly identical to R134a, with variations within ±5%, confirming its suitability as a drop-in replacement without major system modifications.
5. Environmentally, R152a possesses a Global Warming Potential (GWP) of 124 and Ozone Depletion Potential (ODP) of zero, offering a substantial reduction in greenhouse gas emissions and full compliance with the Montreal and Kigali Protocols.

Overall, R152a can be considered a promising, energy-efficient, and environmentally sustainable refrigerant for domestic and commercial refrigeration systems. Its ability to operate efficiently at lower pressures with minimal energy consumption supports its use as a viable replacement for R134a and R22. Future studies should focus on addressing the flammability concerns associated with R152a (classified as A2 by ASHRAE) through the development of advanced safety mechanisms, such as leak detection sensors, flame suppression systems, and improved ventilation designs. Further research can also explore the use of R152a in blended refrigerant systems (e.g., R152a/R600a, R152a/R1234yf) to reduce flammability risks while enhancing thermodynamic stability and overall system efficiency.

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