IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

EXPERIMENTAL INVESTIGATION OF DOMESTIC REFRIGERATOR USING R134A, R32 AND THEIR MIXTURES

[1]Bikkavolu Joga Rao, [2]Deepthimahanthi Abhishekh, [3]Pothula Gannibabu, [4]Mudragada Balu Shankar, [5]Saheb Chaudhary

[1]Associate Professor, [2,3,4,5]UG Students
[1]Mechanical Engineering,
[1]Godavari Institute of Engineering & Technology (A), Rajahmundry, India

Abstract: R134a and R32 are Hydro Fluoro Carbons (HFCs) refrigerants with zero Ozone Depletion Potential (ODP) and low Global Warming Potential (GWP) values. The performance of a domestic refrigerator using R134a, R32, and their mixtures (R134a/R32) with mass fractions varying from 95%/5%, 90%/10%, and 85%/15%, respectively, is evaluated in this experimental study. The R32's lower GWP makes it an asset to use with R134a. The purpose of this study is to examine the performance of R134a and three different combinations in which it is mixed with R32 at a 5% (in mass fractions) escalation in each. The domestic refrigerator compressor was originally designed to operate with R134a. According to the results, the Coefficient of Performance (COP) of the refrigerator with the increase in mass percent of R32 in R134a/R32 mixture. Further, the R134a/R32 blend at a mass fraction % of 85/15 had the highest COP value of (3.28) and COP was found to be increased by 47.1% when compared to the R134a value of (2.23). The test results conclude that the blend R134a/R32 at a mass fraction of 85/15 can be a drop-in replacement for R134a refrigerant.

***Index Terms* - R32, R134a, Ozone Depletion Potential, Global Warming Potential, Coefficient of Performance, Refrigeration Capacity**

I. INTRODUCTION

Since the start of the industrial revolution, anthropogenic Green House Gas (GHG) emissions have increased [1-2]. In developed nations, the main contributors to these emissions include the production of energy, transportation, industry, the commercial and residential sectors, agriculture, and land use [3-6].Various studies indicate that short-term GHG emissions will rise sharply, i.e., when compared with 2010 values, by 36.4 billion metric CO_2-eq. tons over 2020 and 45.5 billion metric CO_2-eq. tons over 2040 [7]. In the worst-case scenario, the global mean surface temperature increase by 2100 (relative to pre-industrial levels) might range from 2.6 to 4.8 K if further steps are not taken to limit GHG emissions [8]. The use of energy is a major factor in climate change [9]. The applications of Heating, Ventilation, and Air Conditioning (HVAC) that regulate the temperature of offices and rooms account for a significant amount of energy consumption in the developed world [1,9,10]. As a result, gases utilized in HVAC applications that have a GWP and ODP values, such as Chloro Fluoro Carbons (CFCs) and Hydro Chloro Fluoro Carbons (HCFCs) refrigerants, significantly contribute to climate change. These refrigerants are being replaced by HFCs such as R134a, R32, etc., [11,12].
Linton JW et al. (1990) [13] investigated the efficiency of domestic heat pumps using R134a and R12. The study discovered that although heating output of R134a was comparable to that of R12, its coefficient of performance (COP) was 15% lower. However, in other studies, it is revealed that R134a is the most popularly used replacement for R12 in vapor compression cycle [14]. Kim et al. (2021) showed that the R32 heat pump outperforms the R410A in terms of heating capacity and coefficient of performance (COP) at low outside temperatures of 10 and 15 °C [15]. Xu et al. (2017) combined R1234yf and R32 in an 80:20 mass concentration ratio to create a heat pump system. The heat pump's performance was assessed in low ambient temperatures. The impact of the gas-injected scroll compressor on the heat pump's heating efficiency was also discussed in this study. The R1234yf/R32 (80/20) system has the highest heating COP when compared to separate R1234yf and R32 refrigerants. It also has the lowest capacity. It was clear that, as compared to the original system, gas injection increased the heating capacity by 16% to 20% and the COP of heating by 13% to 16% [16]. As an alternative to R22, Lee et al. (2012) investigated the thermodynamic performance of an air conditioner using a combination of R32 and R152a with four different compositions. The R32/R152a (50/50) mixture was shown to boost COP by 15.8% and decrease compressor power by 13.7% when compared to the R22 system. The R32/R52a (50/50) blend resulted in a 26.87% reduction in gas charge. It was found that the R32/R152a (36/64) mixture can be utilized as a drop-in replacement with a compressor the same size as the R22 compressor [17].

In the current study, two refrigerants namely R132a and R32 that have low GWP values and zero ODP values are mixed and evaluated to assess the performance of the domestic refrigerator (one of the most used HVAC appliances) which is specified to work with R134a refrigerant.

II. MATERIALS

Using mixtures of R134a and R134a/R32, the current study assesses the performance of the domestic refrigerator. Tests were conducted on with R134a and different mass fractions of R134a/R32 mixture, such as 95%/5%, 90%/10%, and 85%/15%. The refrigerant R134a and R32 were supplied by Om Shriram Engineeirng Services, Secunderabad, India. The properties of R134a and R32 are given in table 1.

Table 1. Shows the physical properties of R134a and R32.

Sl. No.	Physical Parameter	R134a	R32	Reference
1	Boiling point (°C)	-26	-51.7	18,1
2	Freezing point (°C)	-103.3	-136	
3	Critical temperature (°C)	122	78.11	
4	Critical pressure (bar)	4.06	57.82	
5	ρ_v (kg/m^3)	14.35	2.98	
6	ρ_l (kg/m^3)	1295	1055.8	
7	Latent heat of vaporization(kJ/kg)	198.72	315.53	
8	ODP	0	0	19,20
9	GWP	1300	650	
10	Safety	A1	A2	

III. METHODOLOGY

The test rig used for the experiment is a complete vapour compression refrigeration system designed to work with R134a. The schematic view and general view of the domestic refrigerator (with test rig) in shown in Figure 1 and Figure 2 respectively. It is a domestic refrigerator instrumented with two pressure gauges at the inlet and outlet of the compressor for measuring the inlet (suction) and outlet (discharge) pressures. A single thermocouple is used to measure the initial and final temperatures of the water kept in the evaporator.

The test rig is first charged with 150g of R134a with the help of flowmeter and tests were carried out under prevailing atmospheric condition. The average ambient air temperature obtained in the workshop during test period was 30°C.After experimenting, the refrigerant is discharged. The experiment was repeated for mixtures of R134a and R32 in three different mass fractions as 95%/5%, 90%/10%, and 85%/15% respectively.

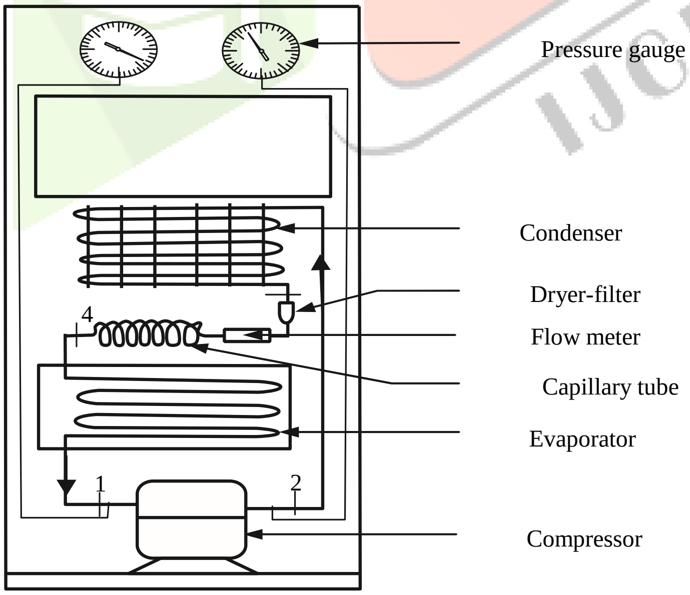

Figure 1. Presents the layout of refrigeration test rig

Figure 2. Represents the refrigeration test rig

The values obtained from the experimentation were used to evaluate the performance characteristics of the domestic refrigerator. Parameters such as refrigeration capacity (Q_w), work done by the compressor (W), COP are considered.

Refrigeration capacity (Q_w) is given by Eq. (1):

$$Q_w = - \left[\frac{m \times 4.18 \times (T_f - T_i)}{t_w \times 60}\right] \quad \text{(KW)} \qquad (1)$$

Where: m = mass of water (kg);

T_i = initial temperature of water (^oC);

T_f = final temperature of water (^oC);

t_w = time taken for temperature difference ($T_2 - T_1$) (in minutes).

Work done by the compressor (W) per second is given by Eq. (2):

$$W = \left[\frac{n \times 3600}{t \times 3200}\right] \quad \text{(KW)} \qquad (2)$$

Where: n = number of blinks;

t = time taken for 'n' number of blinks (in seconds);

The Coefficient of Performance (COP) is the ratio of refrigeration capacity (Q_w) and work done by the compressor per second (W):

$$COP = \frac{Q_w}{W} \qquad (3)$$

IV. Results and discussions

Figure 3 illustrates how R134a refrigerant and R134a/R32 refrigerant mixtures affect a domestic refrigerator's COP. Table 3 displays the experimental input data of different refrigerants while parameters such as mass and temperatures of water, time taken, etc., are considered. Table 4 show the calculated parameters of performance of refrigeration by name refrigeration capacity (Q_w), compressor work done (W) per second, and COP using the input values in table 3. The graph shows that the COP of the domestic refrigerator increased with the addition of R32, while enhancing the refrigerator's cooling capacity/ refrigeration capacity (Q_w) and reducing the amount of work required of the compressor (W). Thus, the R134a/R32 mixture's COP is raised. For R134a, R134a/R32-95/5, 90/10, and 85/15 mixtures, the corresponding COPs are 2.23, 1.89, 2.26, and 3.28. When R134a/R32 mixture at mass fraction 85%/15% is used instead of R134a refrigerant, the maximum COP is increased by 47.1%.

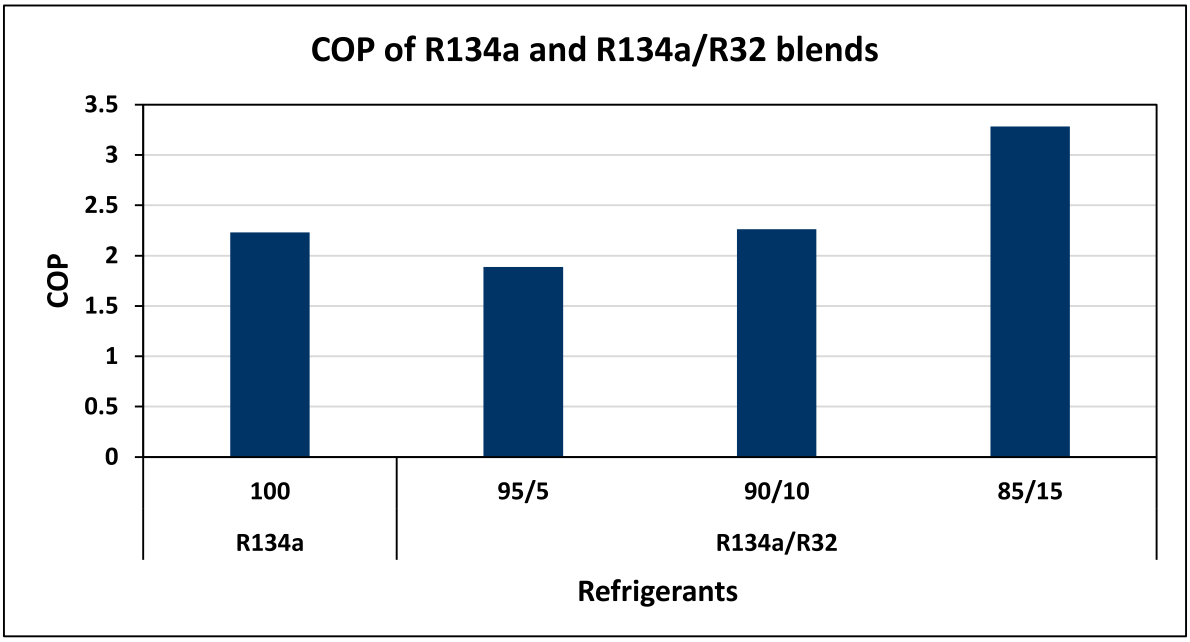

Figure 3: Shows the COP of R134a and R134a/R32 mixtures

Table 3: Shows the input values of different refrigerants

S.No.	Refrigerant Name	Mass Fraction (%)	m (kg)	Water Temperature		t_w (mm:ss)	Energy meter reading	
				T_i (°C)	T_f (°C)		n	t (mm:ss)
1	R134a	100	1	30	16	02:39	10	01:08.0
2	R134a/R32	95/5	1	30	16	03:11	10	01:09.0
3	R134a/R32	90/10	1	30	16	02:49	10	01:10.0
4	R134a/R32	85/15	1	30	16	02:00	10	01:10.8

Table 4: Shows the Refrigeration effect, Work done, and COP values of different refrigerants

S.No.	Refrigerant Name	Mass Fraction (%)	Refrigeration capacity, Q_W (KW)	Work done by compressor, W (KW)	COP
1	R134a	100	0.3693	0.1655	2.232
2	R134a/R32	95/5	0.3076	0.1629	1.888
3	R134a/R32	90/10	0.3469	0.1533	2.263
4	R134a/R32	85/15	0.4886	0.1488	3.283

V. Conclusions

Domestic refrigerators are one of the most popularly used HAVAC appliances in the residential sector which demands for huge amount of energy production in hotter countries worldwide. Therefore, focusing on reducing the usage of high ODP and GWP possessing refrigerants in domestic refrigerators reduces the GHG emissions (CO_2- eq.) by 17%. Hence, in the current study, refrigerants with zero ODP and GWP values such as R134a, R32, and R134a/R32 mixtures at different concentrations by mass fraction % (95/5, 90/10, and 85/15) are used to evaluate the performance of a domestic refrigerator (with test rig) setup. The following conclusions can be drawn from the above results and discussions:

The COP of the domestic refrigerator increased with the addition of R32 despite the sudden decrease @ 95/5 mass fraction % of R134a/R32.This is majorly caused due to the enhancement and reduction in refrigeration capacity and work done by the compressor (per second) respectively. Among the three R134a/R32 mixtures with different mass fractions (%), the mixture with 85%/15% mass fraction had the highest COP which is 47.1% higher as compared to R134a. Ultimately, the study concludes that the refrigerant mixture R134a/R32 at a mass fraction% of 85/15 is viable and can replace R134a in the current domestic refrigeration compressor unit despite the fact that R32 has an A2 level flammability.

Nomenclature

GHG	Greenhouse gases
CO_2-eq.	Carbon di oxide equivalent
HVAC	Heating, ventilation and air conditioning
HCFCs	Hydro chloro fluoro carbons
HFCs	Hydro fluoro carbons
CFCs	Chloro fluoro carbons
COP	Coefficient of performance
GWP	Global Warming Potential
HFCs	Hydro fluoro carbons
m	Mass of water
n	No. of blinks in energy meter
ODP	Ozone Depletion Potential
R134a	Tetrafluoroethane
R32	Difluoromethane
Q_w	Refrigeration capacity / amount of heat released from water (per second)
t	Time taken for “n” no. of blinks
T_i	Initial temperature of water
T_f	Final temperature of water
t_w	Time taken for the drop in water temperature
W	Work done of compressor
ρ_l	Density of Liquid
ρ_v	Density of Vapour

VI. ACKNOWLEDGMENT

The authors sincerely thank the GIET(A), Rajahmundry, for providing laboratory facilities to conduct the research work.

REFERENCES

[1] Mota-Babiloni, A., Navarro-Esbrí, J., Makhnatch, P., & Molés, F. (2017). Refrigerant R32 as lower GWP working fluid in residential air conditioning systems in Europe and the USA. Renewable and Sustainable Energy Reviews, 80, 1031-1042.

[2] Pullagura, G., Vadapalli, S., Prasad, V. V., Bikkavolu, J., Chebattina, K. R., Chava, S. T., & Velisala, V. (2021). Effect of nano additives on fuel properties, engine performance, emission and combustion characteristics of CI engines fuelled with diesel and biodiesel blends: a comprehensive review. Bulletin Monumental, 21(11), 39-50.

[3] Pradeep, V. V. G., & Jogarao, B. (2020). Production, perfomance and emisions of bio diesel from mixture of animal waste fats and degradation of bio diesel over time. International Journal of Innovative Technology and Exploring Engineering, 9(4), 2676-2681.

[4] Pullagura, G., Vadapalli, S., Varaha Siva Prasad, V., Bikkavolu, J. R., Chebattina, K. R. R., Barik, D., & Dennison, M. S. (2023). Influence of dimethyl carbonate and dispersant added graphene nanoplatelets in diesel-biodiesel blends: combustion, performance, and emission characteristics of diesel engine. International Journal of Energy Research, 2023.

[5] Rao, B. J., Pullagura, G., Vadapalli, S., & Chebattina, K. R. R. (2023, December). The effect of CNTs on physicochemical properties of yellow oleander biodiesel-diesel fuel blends. In AIP Conference Proceedings (Vol. 2943, No. 1). AIP Publishing.

[6] Panato, V. H., Pico, D. F. M., & Bandarra Filho, E. P. (2022). Experimental evaluation of R32, R452B and R454B as alternative refrigerants for R410A in a refrigeration system. International Journal of Refrigeration, 135, 221-230.

[7] Bilgen, S. E. L. Ç. U. K. (2014). Structure and environmental impact of global energy consumption. Renewable and Sustainable Energy Reviews, 38, 890-902.

[8] Intergovernmental panel on climate change. Summary for policymakers. In: Climate change 2014: mitigation of climate change. Contribution of Working Group III to the fifth assessment report of the intergovernmental panel on climate change.

[9] Akhmat, G., Zaman, K., Shukui, T., & Sajjad, F. (2014). Does energy consumption contribute to climate change? Evidence from major regions of the world. Renewable and Sustainable Energy Reviews, 36, 123-134.

[10] Pérez-Lombard, L., Ortiz, J., & Pout, C. (2008). A review on buildings energy consumption information. Energy and buildings, 40(3), 394-398.

[11] UNEP. Report of the Technology and Economic Assessment Panel. Montreal Protocol on Substances that Deplete the Ozone Layer; UNEP: Nairobi, Kenya, 2016.

[12] Benhadid-Dib, S.; Benzaoui, A. Refrigerants and their environmental impact Substitution of hydro chlorofluorocarbon HCFC and HFC hydro fluorocarbon. Search for an adequate refrigerant. Energy Procedia 2012, 18, 1611–1623.

[13] Linton, J. W., Snelson, W. K., & Hearty, P. F. (1989). Performance comparison of refrigerants R-134a and R-12 in a residential exhaust air heat pump. ASHRAE Transactions (American Society of Heating, Refrigerating and Air-Conditioning Engineers); (USA), 95(CONF-890609-).

[14] Bolaji, B. O. (2010). Experimental study of R152a and R32 to replace R134a in a domestic refrigerator. Energy, 35(9), 3793-3798.

[15] Kim, D., Lee, D., Lee, M., Chung, H. J., & Kim, Y. (2021). Energy performance evaluation of two-phase injection heat pump employing low-GWP refrigerant R32 under various outdoor conditions. Energy, 214, 119098.
[16] Xu, S., Fan, X., & Ma, G. (2017). Experimental investigation on heating performance of gas-injected scroll compressor using R32, R1234yf and their 20wt%/80wt% mixture under low ambient temperature. International journal of refrigeration, 75, 286-292.
[17] H. S. Lee, H. J. Kim, D. G. Kang and D. Jung, Thermodynamic performance of R32/R152a mixture for water source heat pumps, Energy 40 (2012) 100–106, doi: 10.1016/j.energy.2012.02.024.
[18] Direk, M., & Soylu, E. (2018). The effect of internal heat exchanger using R1234ze (E) as an alternative refrigerant in a mobile air-conditioning system. Strojniški vestnik-Journal of Mechanical Engineering, 64(2), 114-120.
[19] Roy, Z., & Halder, G. (2020). Replacement of halogenated refrigerants towards sustainable cooling system: A review. Chemical Engineering Journal Advances, 3, 100027.
[20] Kassas, M. (2015). Modeling and simulation of residential HVAC systems energy consumption. Procedia computer science, 52, 754-763.