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Research Article

A Brief Comparison of R1234YF as an Alternative Refrigerant to R134A in Domestic Refrigerator

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A B S T R A C T

This study examines effect of R1234YF and R-134A in a domestic refrigerator under identical conditions. R11, R12 and R22 are the commonly used refrigerants but they are found to have high ODP and thus have harmful effects on the ozone layer. R134A which is found to be a suitable candidate to replace R12 and is being used as alternate refrigerant but this also has a high GWP. An energy consumption trial had been run to evaluate the performance of R1234YF as drop-in replacement of R134A in a domestic refrigerator and it was found that refrigerant R1234YF performs well which is validated with the available literature.

Keywords: Ozone Depletion Potential, Global Warming, Refrigeration, R134A, R1234YF.

Introduction

Over past decades different refrigerants have been used in refrigeration and air conditioning devices and have found to be responsible for destruction of the ozone layer.[5] The most commonly used refrigerants for such refrigerators in recent times were R11, R12 and R22 but they were found to have high ODP and thus had harmful effects on the ozone layer.[10] More interest has been gained in recent years to find alternative work fluids and R134a was found to be a suitable candidate to replace R12 and is being used successfully in small devices like in domestic refrigerators, water coolers and air-conditioning.[8] R134A has a high GWP and global warming has recently been one of mankind's most important issues and so there is a huge necessity to shift from the conventional R134A used in refrigerators to refrigerants with lower GWP and ODP.[9] R1234YF exhibits similar thermodynamic properties as seen in Table 1.

The GWP of R1234YF is four times lower than that of conventional refrigerants, even lower than carbon-dioxide.[6] Table 2 shows ODP and GWP of common refrigerants.

Table 1.Thermodynamic properties of HFO-1234YF and HFC-134A

Properties	R-1234yf	R-134a
Boiling point	-29 ^{0}C	-26 ^{0}C
Critical point	95 ^{0}C	102 ^{0}C
Liquid density at 25^{0}C	1.094	1.207
Vapour density at 25^{0}C	37.6	32.4
Source: REFPROP 8.0 Software.		

Literature Review

It is observed that limited studies considered low Global Warming Potential (GWP) refrigerants. Work is available in many works via literature to determine whether R1234YF can be used directly to replace R134A, with minor changes in the vapor compression refrigeration systems.

Table 2.ODP and GWP of common refrigerants[2]

Refrigerant	Ozone Depletion Potential (*ODP*)	Global Warming Potential (*GWP*)
R-11 Trichlorofluoromethane	1	4000
R-12 Dichlorodifluoromethane	1	2400
R-13 B1 Bromotrifluoromethane	10	2000
R-22 Chlorodifluoromethane	0.05	1700
R-134a Tetrafluoroethane	0	1300
R1234YF 2, 3, 3, 3-tetrafluoropropene	0	4
R-718 Water - H_20	0	0
R-729 Air	0	0

Rajamanickam C et al. (2016) studied the GWP and ODP impacts of R134A. The results showed that R1234YF has lower GWP and can be used as a successful replacement for R134A.[8]

Aziz A, Mainil AK, (2017) studied the difference in properties between HFC 134a and HCR 134a. The study showed that using different expansion device HCR 134a can be used to replace HCF134a as HCR134A had a lower GWP as well.[1]

Atilla G, Vedat O. (2018) studied ways of enhancing the performance of refrigerant R134A. The COP was improved by using plate-type LSHX utilization.[3]

Li Z, Liang K, Jiang, H. (2019) conducted various experiments to find out the thermodynamic properties of the refrigerant R1234YF. The findings showed that the properties matched well with R134A and can even be used as its replacement.[4]

Longo G et al. (2019) worked on the on-going phase out of R134A and tried to find out the possible replacement for the refrigerant. The study showed that with lower GWP R1234YF and properties that are similar and comparable R1234YF can be successfully used as a replacement for R134A.[7]

According to the literature it is better to focus on R1234YF (GWP>1) as the most acceptable alternative to R134A.

Figure 2.Evaporator chamber of refrigerator

Figure 3.Energy meter

Experimental Procedure

The study is conducted on a domestic refrigerator in which R134A was used. The temperature was set at 20^0C and 20 litres of water was kept inside the refrigerator for 24 hours. The same procedure was repeated again with the temperature set at 10^0C, and subsequently with temperature at 0^0C.

The refrigerant was changed to R1234YF. The experiment procedure was repeated as done with R134A.

The energy consumption was measured using the energy meter.

The values in the energy meter were all reset, and the refrigerator was turned on. After 24 hours it was observed that the compressor had run for about 486 minutes. The kwh unit was also observed. Once the experiment was repeated for various parameters, graphs were plotted to easily understand the power consumption scheme.

Result & Discussion

Comparison of Cabinet Temperature to Power Consumption for R134A

From the calcultions, the relation between power consumption and cabinet temperature has been plotted below. From the graph it can be said that Power consumption is high when the temperature is lowered, and as the temperature approaches towards the ambient level of 20^{0}C the power consumption lowers.

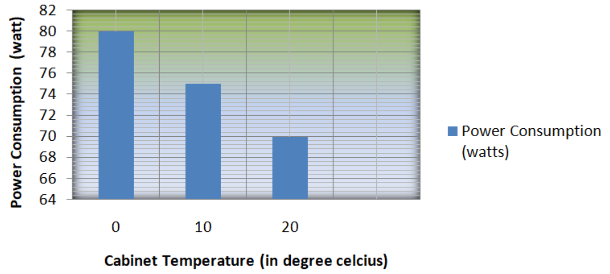

Figure 4.Mean power consumption for R134A

Comparison of cabinet temperature to COP for R134A

From calculation, the graph of COP correlation to Cabinet temperature can be plotted. From the graph we can conclude that the COP is low at 0^{0}C while it goes on increasing as the temperature is slightly increased and is near its peak value when the temperature is around 20^{0}C.

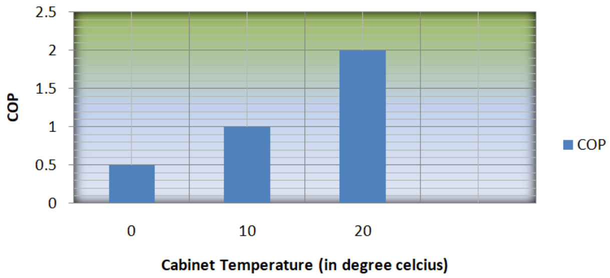

Figure 5.Evaporator chamber of refrigerator

Comparison of cabinet temperature to power consumption for R1234YF

From the calcultions above, the relation between power consumption and cabinet temperature has been plotted velow. From the graph it can be said that Power consumption is high when the temperature is lowered, and as the temperature approaches towards the ambient level of 20^{0}C the power consumption lowers.

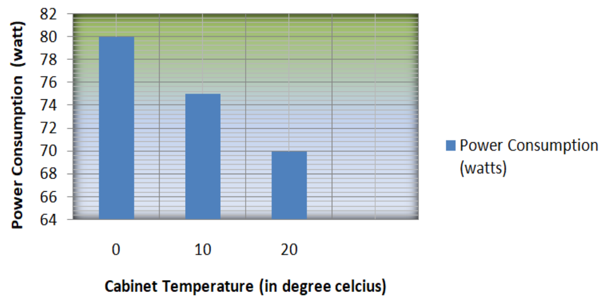

Figure 6.Mean power consumption for R1234YF

Comparison of Cabinet Temperature to COP for R1234YF

From calculation, the graph of COP correlation to Cabinet temperature can be plotted. From the graph we can conclude that the COP is low at 0^{0}C while it goes on increasing as the temperature is slightly increased and is near its peak value when the temperature is around 20^{0}C.

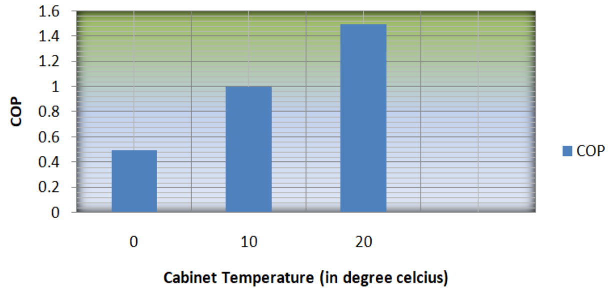

Figure 7.COP co-relation with cabinet temperature for R1234YF

Conclusion

As revealed in the literature survey and data of performance obtained through this study we can conclude that:

- Identical effect R1234YF in comparison with R-134A was produced in terms of temperature for cooling same mass in refrigerator.
- The COP obtained was similar to the COP of R134A, with the maximum COP at 20^{0}C which can be considered as ambient temperature.
- Under identical cooling capacities R1234YF consumes approximately 2% higher energy than R134A in domestic refrigerator.
- R1234YF is a worthy environmentally friendly choice in comparison to R134A for refrigerators working on VCRS cycle.

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Nomenclature

CFCs: Chlorofluorocarbons

COP: Coefficient of Performance

ODP: Ozone Depletion Potential

GWP: Global Warming Potential

VCRS: Vapour Compression Refrigeration System

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