Performance Study Of Ecofriendly Refrigerant Mixture As An Alternative To R134a In A Household Refrigerator

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Abstract— R134a is a popular, environmentally friendly refrigerant that is thought to be better suited for use in household refrigerators. It has a lower global warming potential but is protective for the ozone layer. R152a and R600a were combined in this study's refrigerant mixture at a 76:24 mass ratio. By ASHRAE, this blend is known as R430A. It is almost azeotropic with zero ODP and low GWP (Global Warming Potential) of 107. It is regarded as an R134a substitute that can work. A theoretical performance study was conducted using the REFPROP 9.0 database software as a property reference. The alternative refrigerants selected had better properties than R134a. In addition, the refrigeration cycle performance of R134a and R430A was analyzed using CYCLE_D software to predict various performance characteristics. As a result of this study, the selected alternative refrigerant mixture R430A proved to be an excellent substitute for R134a.In terms of zero ODP, low GWP, and environmental friendliness, the suggested combination appears to be an extended-life refrigerant to replace R134a.

Keywords: low GWP refrigerants, performance, ecofriendly, R430A, Cycle-D

INTRODUCTION

R134a is an almost non-toxic, ecologically benign refrigerant [1], however it has a high GWP. R134a, a refrigerant used in home refrigerators, was one of six greenhouse gas reduction targets set forth in the Kyoto Protocol [2]. As a result, the usage of R134a must be drastically reduced in accordance with the Kyoto Protocol [3].It is critical to identify better replacements for high global warming refrigerants from the standpoints of the environment, ecology, and health [4].The EU Guidelines 517/2014 were just passed in an additional effort to lessen the consequences of worldwide warming. In order to comply with the limit established by these legislation, the refrigerant sector is switching to refrigerants with a low greenhouse gas emissions Potential [5].R430A, a blend of R152a and R600a with a mass ratio of 76:24, was developed and approved by ASHRAE. It can replace R134a since it is almost azeotropic, has low GWP of 107 [6].Mani and Selladurai [7] used a vapour compression refrigeration system to test the innovative R 290/R600a refrigerant mixture. According to the findings of their research, the refrigerant mixture has a refrigerating capacity 28.6 percent to 87.2 percent higher than R134a. B.O. Bolaji [8] carried out an experimental study in a home refrigerator by substituting R134a with R152a and R32. According to the findings of the tests, the average COP produced using R152a is 4.7% higher than that obtained with R134a.When employing R430A instead of R134a, Mohan Raj [9] examined at the theoretical energy efficiency of a home refrigerator. At all operating temperatures, it was discovered that R430A had a better coefficient of performance than R134a by 2.6 to 7.5 percent and used 1 to 9 percent less compressor power. Baskaran et al.[10-20] investigated the effectiveness of a gas compression refrigeration system using a variety of environmentally friendly refrigerants and refrigerant mixes, and compared the findings to R134a as a viable replacement. The objective of this work is to examine the effectiveness of low GWP refrigerant combinations in the refrigeration system of a household refrigerator in order to replace R134a.

2.0 MATERIALS AND METHODS

2.1 PROPERTIES OF REFRIGERANTS

Table 2.1 lists the properties of the refrigerants at atmospheric pressure obtained from REFPROP 9.0 [21]

Table 2.1 Properties of several refrigerants.

Characteristics	**Tetrafluoroethane (R134a) (CF3CH2F)**	**Hydrocarbon Blend (R290/R600a)**	**Difluoroethane (R152a)**	**76% R152a and 24% R600a (R430A)**
Molar Mass (kg/kmol)	102	50	66	64
Boiling point (°C)	-26	----	-24	----
Critical Temp (°C)	101	116	113	107
Critical Pressure (Mpa)	4.06	4.1	4.5	4.09
Critical Density (kg/m³)	511	220	368	316
Latent Heat (KJ/kg)	216	394	329	328
limits of Explosive (% by vol)	----	2	5	----
ODP	0	0	0	0
GWP	1370	20	133	110

2.2 CYCLE_D MODEL

The NIST CYCLE D model was used in this investigation [22]. The system for CYCLE D (SLHX) consists of a compressor, outlet line, condenser, expander device, evaporator, the suction side of the compressor line, and a supplemental suction line heat exchanger. Figure 2.2 illustrates how the cycle is bordered by 11 states that represent crucial points in a real system.The following are the states: (1) Condenser inlet (2) Cylinder intake before compression (3) Cylinder outlet after compression (4) inlet to condenser (5) condenser saturated vapour (6) condenser saturated liquid (7) outlet to condenser (9) inlet to evaporator (10) Evaporator Saturated vapour (11) Evaporator exit. The rating parameters include a condensing temperature of 45°C and an evaporation temperature of -30°C to 20°C.The average of the bubble and dew point temperatures is used in CYCLE D to determine the condensed temperature for mixes. The dew point temperature and the average of the vaporizer input temperatures are used to determine the evaporating temperature. In this experiment, the sub cooling and superheat is set at 0°C.Both the suction and outflow lines are presumed to be adiabatic. The estimated compressor efficacy of 1.0 was maintained for all of the refrigerants under study.

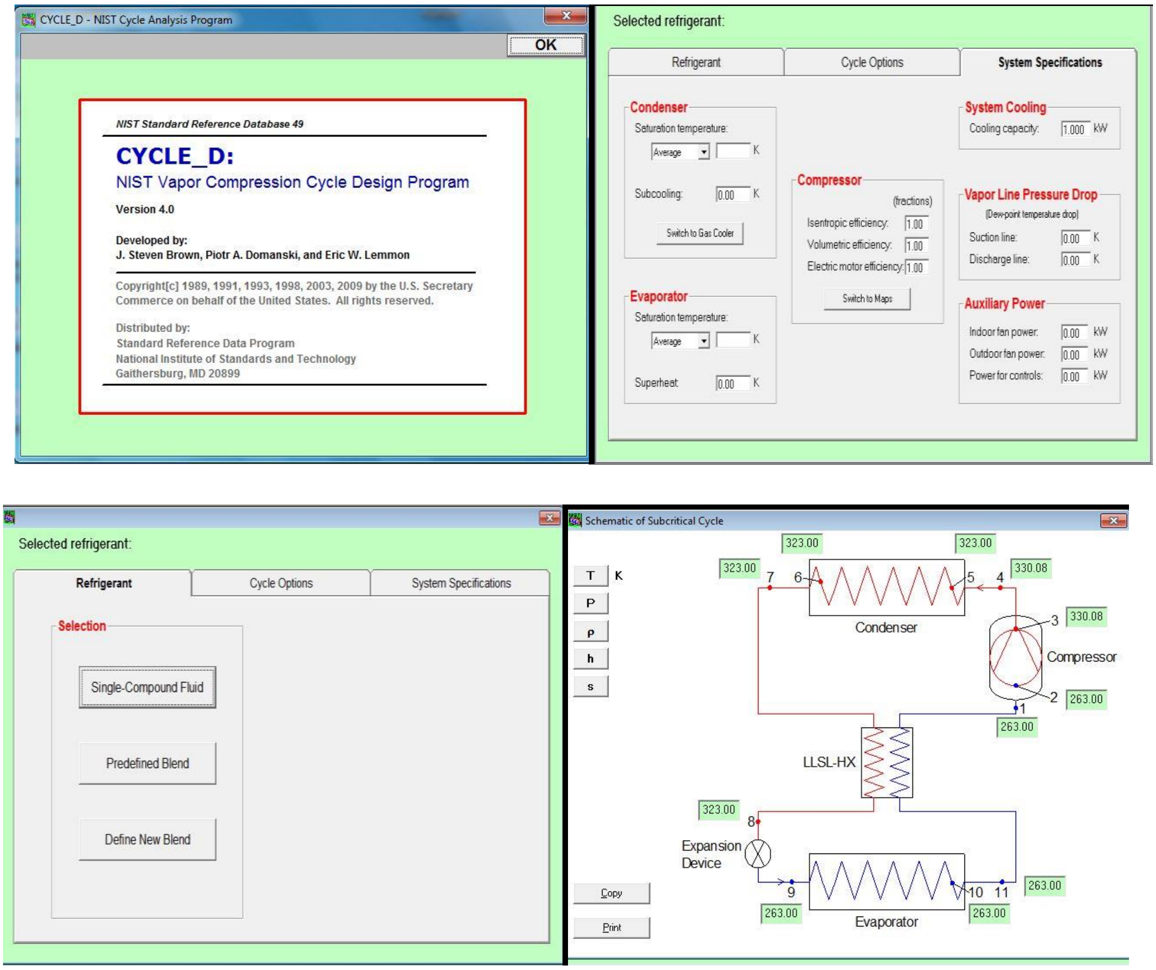

Figure 2.1 Screens of CYCLE_D software

The efficiency of the volumetric compressor and the efficiency of the electric motor were likewise maintained as 1.0.A fluid line heat exchange system is supposed to have an efficiency of 1.0.Parasitic qualities are maintained constant under all circumstances.The pressure ratio, discharge temperature, coefficient of performance, compressor power, refrigerating effect mass flow rate, volumetric refrigerating capacity, compressor work, and condenser duty for a set of refrigerants have all been calculated using the CYCLE_D model in this analysis. The effects of evaporating temperature on the aforementioned parameters have also been examined.

3.0 RESULTS AND DISCUSSIONS

In this section, the effect of evaporating temperature ranging from -30^{0}C to 20^{0}C on various refrigeration cycle performance parameters are discussed for the selected low Emission refrigerant mixture.

3.1Effect of Evaporating Temperature on Pressure Ratio

For a condensing temperature of 50°C, Figure 3.1 depicts the pressure ratio's variation with evaporating temperature. In comparison to R430A, R134A has a larger pressure ratio.

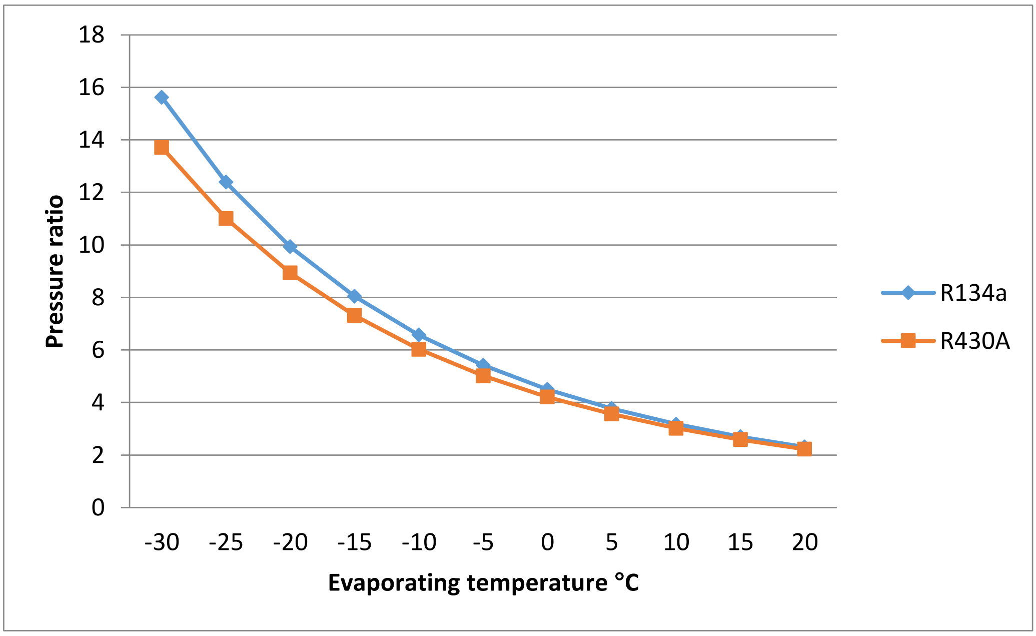

Figure 3.1 Pressure ratio variation with evaporation temperature

3.2 Effect of Evaporating Temperature on Discharge Temperature

Figure 3.2 depicts the fluctuation in discharge temperature for R134a and R430A at 50°C condenser temperature with variable evaporator temperature. The graph demonstrates that when evaporator temperature rises, discharge temperature falls. At lower evaporation temperatures, it is important. Results indicate that R430A has a greater discharge temperature than R134a.

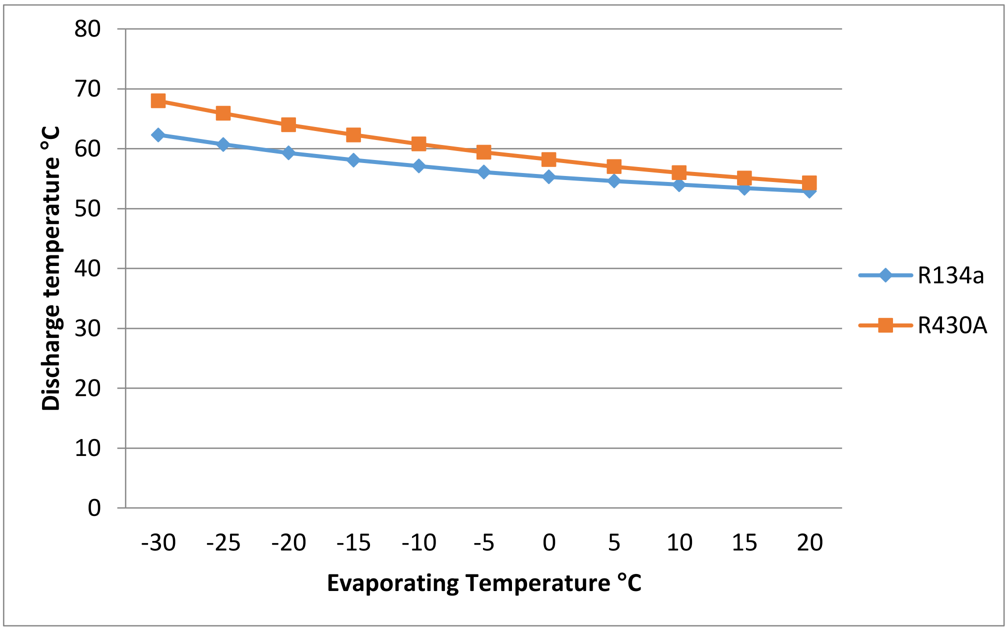

Figure 3.2 Discharge temperature variation with evaporation temperature

3.3 Effect of Evaporating Temperature on Refrigerating Effect

The refrigerating impact of R134A and R430A varies with varying evaporating temperature at 50°C condenser temperature, as shown in Figure 3.3. The graph demonstrates that as the evaporation temperature rises, the refrigerating effect also rises. R430A has a greater refrigerating impact than R134a.

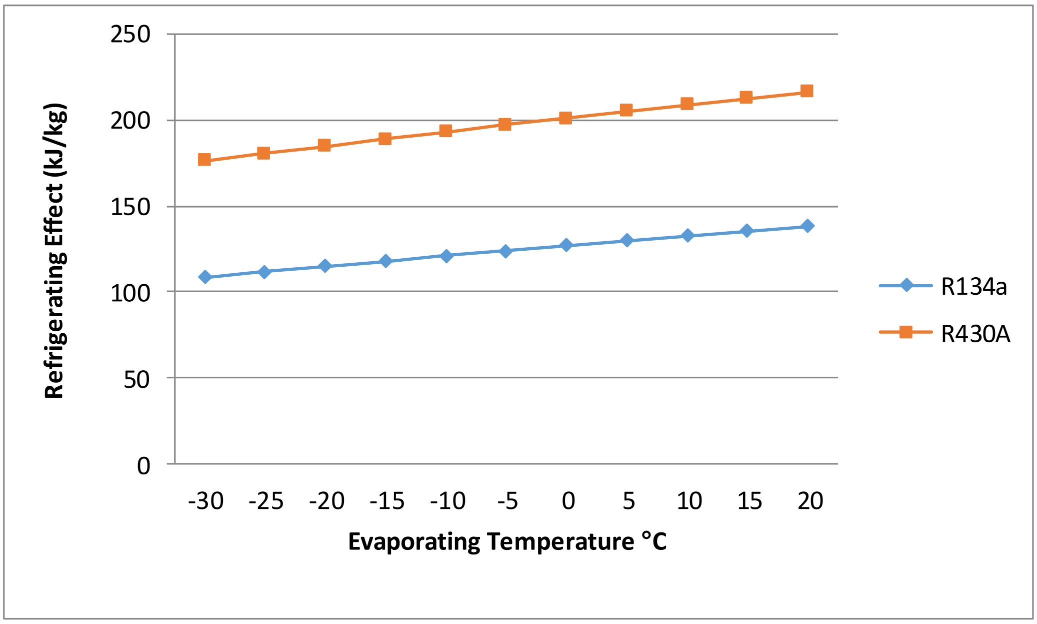

Figure 3.3 Variation of Refrigerating effect with evaporating temperature

3.4 Effect of Evaporating Temperature on Condenser Duty

Figure 3.4 depicts the fluctuation in condenser duty for R134a and R430A at 50°C condenser temperature with variable evaporator temperature. The graph demonstrates that when evaporator temperature rises, condenser duty falls. Results indicate that compared to R134a, R430A has a higher condenser duty.

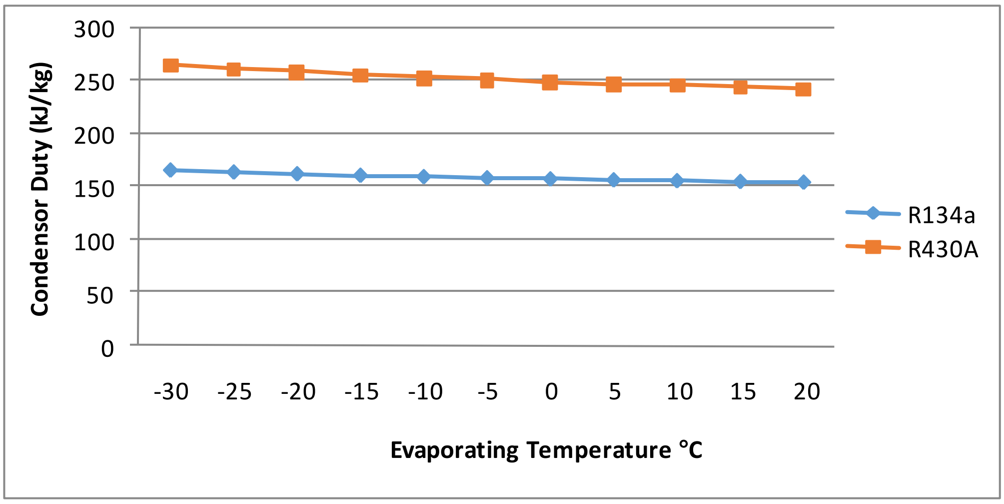

Figure3.4 Variation of Condenser duty with evaporating temperature

3.5 Effect of Evaporating Temperature on Compressor Work

The change of compressor operation with varying evaporator temperature at 50°C condenser temperature of R134a and R430A is shown in Figure 3.5. The graph demonstrates that when evaporator temperature rises, compressor work decreases. Compared to R134a, R430A requires more compressor work. At lower evaporation temperatures, the fluctuation in compressor work is more pronounced.

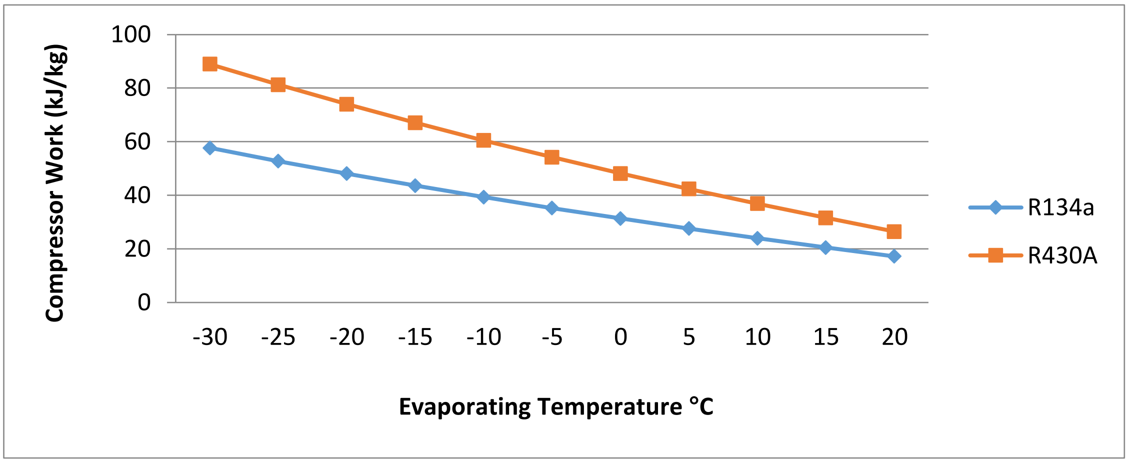

Figure 3.5 Variation of Compressor work with evaporating temperature

3.6 Effect of Evaporating Temperature on Coefficient ofPerformance

The impact of evaporator temperature on coefficient of performance is depicted in Figure 3.6. With an increase in evaporator temperature, the pressure ratio across the compressor lowers, reducing the work required by the compressor while increasing cooling capacity due to an increase in refrigerating effect. The coefficient of performance (COP) is thereby increased by the combined influence of these two components. Over the spectrum of evaporation temperatures, the COP value of the R430A refrigerant is higher than that of R134a. Additionally, it is discovered that the COP increases along with the rise in evaporation temperature.

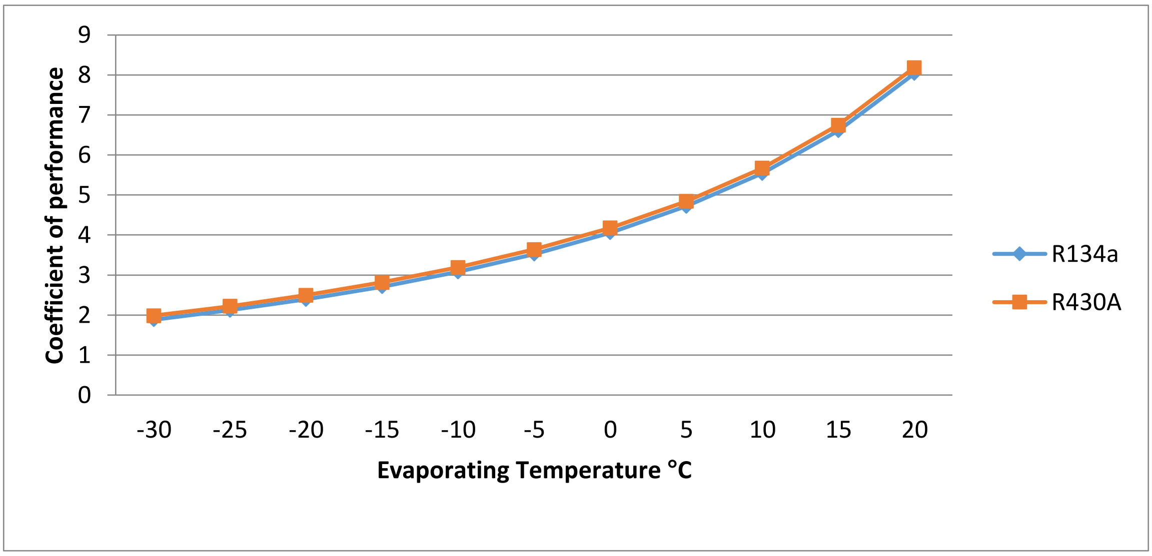

Figure 3.6 Coefficient of performance variation with evaporation temperature

3.7 Effect of Evaporating Temperature on Volumetric Cooling Capacity

Figure 3.7 depicts the difference in volumetric cooling capacity for R134a and R430A at 50°C condenser temperature with variable evaporating temperature. The graph demonstrates that as the evaporation temperature rises, the volumetric cooling capacity also rises. Compared to R134a, R430A has a lower VCC.

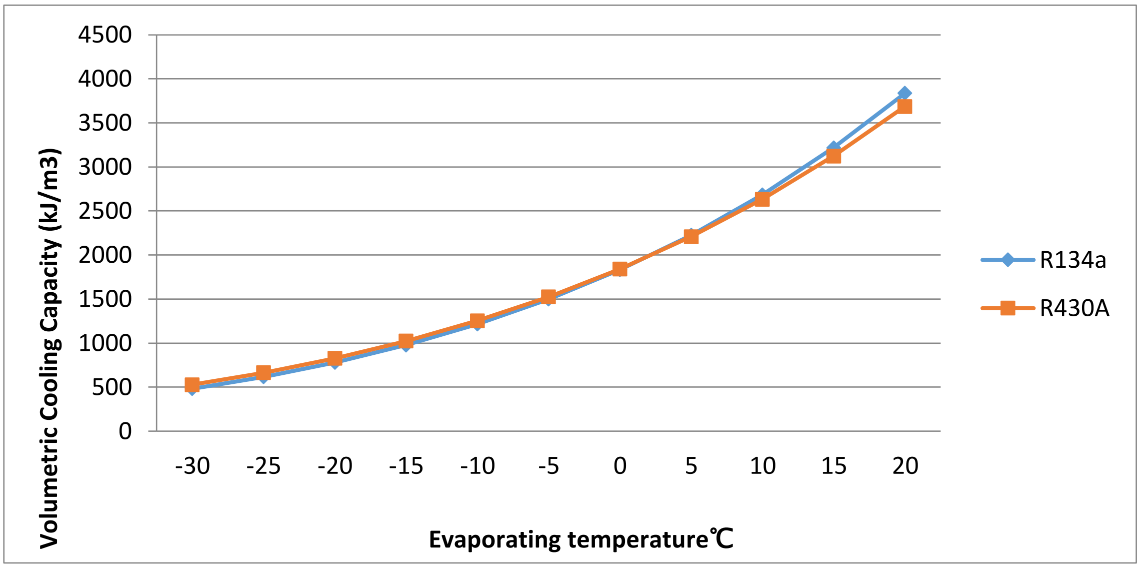

Figure 3.7 Volumetric cooling capacity varies as evaporation temperature increases.

3.8 Effect of Evaporating Temperature on Compressor Power

Figure 3.8 depicts the compressor power variation for R134a and R430A at 50°C condenser temperature with variable evaporator temperature. The graph demonstrates how compressor power reduces as evaporator temperature rises. R430A use less compressor power than R134a.

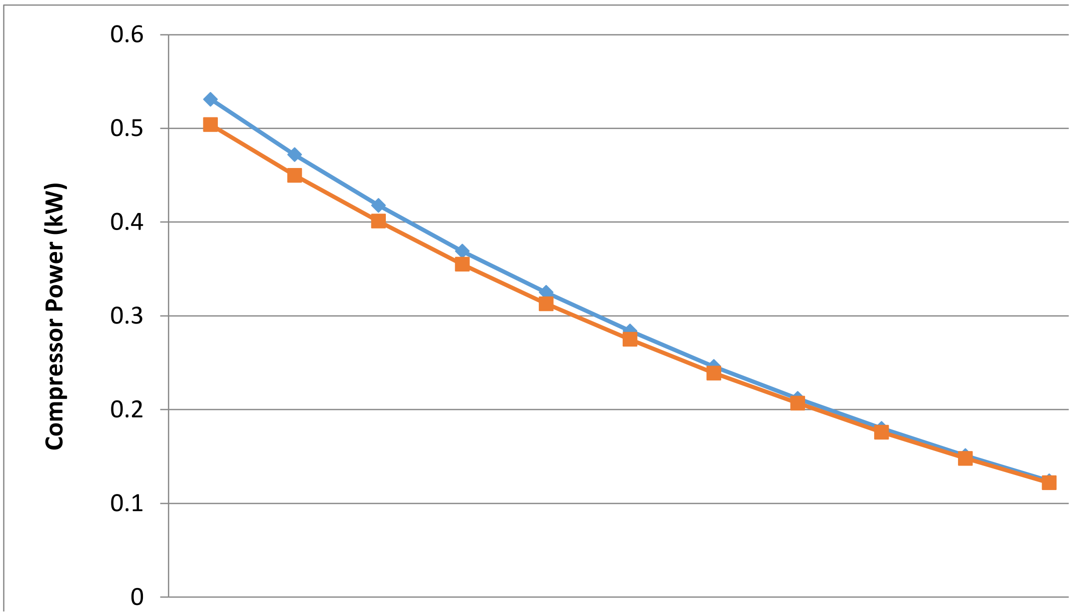

Figure 3.8 Compressor power variation with evaporation temperature

3.9 Effect of Evaporating Temperature on Mass Flow Rate

Figure 3.9 displays the fluctuation in refrigerant mass flow for R134a and R430A at 50°C condenser temperature with increasing evaporator temperature. The graph demonstrates that when evaporator temperature rises, refrigerant mass flow slightly declines. Results indicate that R430A has a substantially lower refrigerant mass flow than R134a.

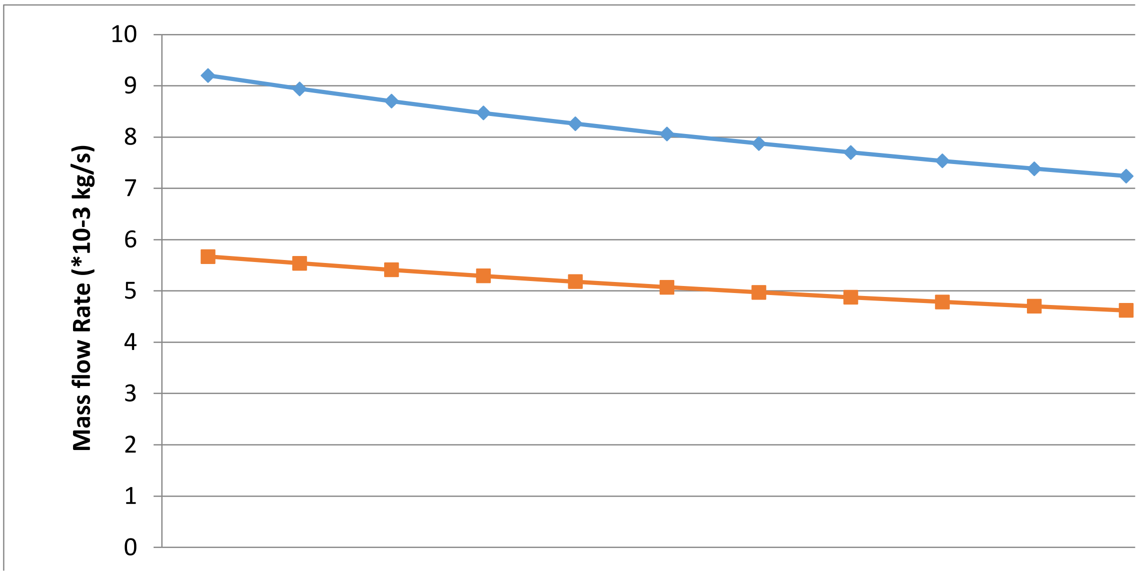

Figure 3.9 Mass flow rate variation with evaporation temperature

4.0 CONCLUSIONS

This research is aimed towards the use of a more environmentally friendly refrigerant as a replacement for R134a. The new environmentally friendly alternative refrigerant shares features with R134a.

- The new alternative environmental friendly refrigerant mixture R430A has properties similar to those R134a.
- Due to their lower density than R134a, the R430A refrigerant combination requires less of a charge in the vapour compression refrigeration system.
- Latent heat of R430A is higher than that of R134a. Hence these refrigerants will give higher refrigerating capacity
- The pressure ratio of R430A is approximately 8.21% lower than that of R134a.
- The refrigerating effects of the alternative refrigerant mixture R430A is higher than that of R134a by about 37.30%.
- The Compressor power of the alternative refrigerant mixture R430A is lower than that of R134a by about 3.69%.
- The mass flow rates of the alternative refrigerant mixture R430A is lower than that of R134a by about 37.28%.
- The alternative refrigerant mixture R430A has a volumetric cooling capacity that is 3.06% higher than R134a.
- The alternative refrigerant mixture R430A has a performance coefficient that is approximately 3.63% greater than that of R134a.

REFERENCES

[1] W. Dietrich, “A positive outlook for the future”, ASHRAE *Journal*, Vol. 35, pp. 64-65, 1993.

[2] W.T. Tasi, “An overview of environmental hazards and exposure and explosive risk of hydro fluorocarbon HFCs”, *Journal of Chemosphere*,
Vol. 61, pp.1539-1547, 2005.

[3] Kyoto protocol, United Nations Framework Convention on Climate Change, United Nations, New York, USA, 1997.

[4] E. Johnson, “Global warming from HFC”, *Environmental Impact Assessment Review,* Vol. 18, pp. 485-492, 1998.

[5] Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing
Regulation (EC) No 842/2006 (eurlex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0517&from=EN)

[6] Park, KJ & Jung, DS 2009, ‘Performance of alternative refrigerant R430A on domestic water purifiers’, Journal of Energy Conversation Management, vol.50, pp.3045–3050.

[7] Mani, K., V. Selladurai, 2008, ‘Experimental analysis of a new refrigerant mixture as drop-in replacement for CFC12 and HFC134a’,
International Journal of Thermal Sciences, vol.47, no.11, pp.1490-1495.

[8] Bolaji, B.O, 2010, ‘Experimental study of R152a and R32 to replace R134a in a domestic refrigerator’, Journal of Energy, vol.35, pp. 3793–3798.

[9] Mohan raj M 2013, ‘Energy performance assessment of R430A as a possible alternative refrigerant to R134a in domestic refrigerators’,
Energy for Sustainable Development, vol.17, pp.471–476

[10] Baskaran, A. and Koshy Mathews, P., 2013. Energy and exergy analysis of a vapour compression refrigeration system with R134a, R152a
and RE170. *Archives Des Sciences*, *66*(3), pp.1-15

[11] Baskaran, A. and Mathews, P.K., 2012. A Performance comparison of vapour compression refrigeration system using various alternative refrigerants. *International Journal of Scientific & Engineering Research*, *3*(10), pp.1-8.

[12] Baskaran, A. and Mathews, P.K., 2012. A Performance comparison of vapour compression refrigeration system using Eco friendly refrigerants of
low global warming potential. *International journal of scientific and research publications*, *2*(9), pp.1-8.

[13] Baskaran, A. and Mathews, P.K., 2012. Thermal analysis of vapour compression refrigeration system with R152a and its blends R429A, R430A,
R431A and R435A. *International Journal of Scientific & Engineering Research*, *3*(10), pp.1-8.

[14] Baskaran, A. and Mathews, P.K., 2012. Comparative Study of Environment Friendly Alternatives to R12 and R134a in Domestic Refrigerators.
European Journal of Scientific Research, vol92, (2), pp.160-171.

[15] Baskaran, A. and Mathews, P.K., 2015. Investigation of New Eco Friendly Refrigerant Mixture Alternative to R134a in Domestic Refrigerator.
Australian Journal of Basic and Applied Sciences, *9*(5), pp.297-306.

[16] Baskaran, A. and Mathews, K., 2015. Thermodynamic Analysis of R152a and Dimethylether Refrigerant Mixtures in Refrigeration System.
Jordan Journal of Mechanical & Industrial Engineering, *9*(4).

[17] Baskaran, A. 2018, Thermodynamic Analysis Of Di Methyl Ether And Its Blends As Alternative Refrigerants To R134a in a Vapor
Compression Refrigeration System, e-ISSN (O): 2348-4470, Volume 5, Issue 12.

[18] Baskaran, A. 2018, Effects Of Sub-Cooling On The Performance Of R152a And RE170 As Possible Alternatives in a Domestic Refrigeration
System, ISSN NO: 2277-8160 Volume 7, Issue 11

[19] Baskaran, A. 2018, Thermodynamic and Thermo physical Assessment of Dimethyl Ether and Its Blends Application in Household Refrigeration
ISSN NO: 2279-543X, Volume 7, Issue 2.

[20] Baskaran, A. and Matthews, K., 2017. Exergetic analysis of a vapour compression

refrigeration system with R134A, RE170, R429A, R435A.
International Journal of Current Advanced Research, 6(6), pp.4029-4036.

[21] REPPROP, Reference fluid thermodynamic and transport property. NIST standard reference data base 23- version 9.0 Gaithersburg (MD), NIST.

[22] CYCLE_D, Vapour compression cycle design, NIST standard reference data base 23- version 4.0 Gaithersburg (MD), NIST.