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Thermodynamic Analysis of Eco-Friendly Refrigerant Mixtures as an Alternative to HFC-134a in Household Refrigerator

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ABSTRACT

Nowadays, research has been focused on refrigerants from Hydrofluorocarbons (HFCs), which are not harmful to the ozone layer. Because of replacing refrigerants from chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). HFCs are used in many applications, including refrigerants, aerosols, solvents, and blowing agents for insulating foams. However, some HFCs have relatively high global warming potential (GWP) and are subject to further examination due to growing concerns about global climate change. The present work's main objective is to select eco-friendly refrigerants from AC5, R430A and R440A, combining two or more refrigerants from HC, HFC and HFO groups as a direct substitute HFC-134a in a household refrigerator. The performance of the domestic refrigerator with liquid suction heat exchanger (LSHX) was compared in terms of compressor discharge temperature, coefficient of performance (COP), volumetric cooling capacity (VCC), and power consumption of a compressor. It was found that the average COP of R440A and R430A was higher by approximately 2.5% and 1.47% than HFC-134a. However, the COP of AC5 was 6.1% lower than that of HFC-134a. The VCC of R430A is almost equal to HFC-134a. The results also show that AC5, R440A and R430A consume less power than HFC-134a. The compressor outlet temperature with R440A, AC5 provide higher values than HFC-134a, which affects the compressor life. The best overall performance was achieved with the refrigerant R430A in the household refrigerator and suggested an alternative to HFC134a, which also has a very low GWP from the environmental safety perspective.

1. INTRODUCTION

Environmental pollution is aggravated by the excessive use of refrigerators and air conditioners worldwide, along with automobiles. The ozone layer is damaged by releasing refrigerants containing chlorine into the atmosphere. Due to this, dangerous ultraviolet radiations are coming to the surface of the earth. As a result, the earth's surface temperature is increasing rapidly, leading to weather change. The effect of these greenhouse gases can be expressed in terms of GWP. In the last 30 years, CFCs and HFCs are widely used in refrigerators and air conditioners. However, ODP and GWP values are very high for these refrigerants, which cause environmental pollution. According to Montreal protocol, chlorofluorocarbons and HCFC are entirely prohibited in the air conditioning and refrigeration sector due to this higher ODP value. Therefore, in place of these refrigerants, HFC refrigerants are introduced, but the main problem with these refrigerants is that they have a higher GWP value. Therefore, these should be banned in the coming years based on the Kyoto Protocol. Therefore, R134a has to be phased out by 2021. In addition, most of the developing countries are drastically reducing their HFC production and consumption. Therefore, there is a greater demand for an adequate replacement for HFC-134a to adapt to existing and new systems.

Hoe et al. [1] experimented with R600a, which is a substitute to the R12 in a household refrigerator. They analyzed theoretically with the help of software REFPROP, and then performed a series of tests with this refrigerant substitute to R134a in a fridge. Jung et al. [2] conducted an experiment with a mixture of HC290 / HC600a (60:40 by mass) as a direct substitute for R12 in a refrigerator and concluded that COP and power efficiency improved by 2.5 and 3.8%. Fatouh and Kafafy [3] studied the performance of the household refrigerator that works with the refrigerant mixture (consist of HC290 / HC600 / HC600a in the ratio 60:20:20 by mass) a substitute to HFC-134a. It has been reported that the power consumption of compressor operating with an LPG blend was 5.1% lower than HFC-134a with 7.5% higher COP. Garland and Hadfield [4] studied the environmental impact of the R600a natural refrigerant installed in the hermetic compressor of the household refrigerator. The results showed that the R600a is superior to the R134a, with the compressor having its 15-year cycle.

Dalkilic and Wongwises [5] conducted a theoretical analysis on the refrigerator using various alternative refrigerants and refrigerant mixtures as an alternative to R12 and R22. They concluded that HFC and HC refrigerants could be used as alternatives to the above refrigerants from that theoretical analysis. Naushad et al. [6] had conducted an energy and exergy analysis of R1234yf, R1234ze (E) and R134a in a domestic refrigeration system. Finally, they concluded that HFO-1234yf could be used as a good substitute for HFC-134a at a higher value of the evaporator temperature, and R1234ze (E) can be used as a suitable replacement after specific modification. Rastietal [7] conducted an experiment on R600aand R436a consisting of 46% and 50% of isobutane and propane) as an alternative to R134a in a household refrigerator. The results concluded that the compressor energy consumption and volumetric cooling capacity was reduced by about 15% and 8%, respectively. Joybari et al. [8] carried out the exergy analysis to find the optimal load of HC-600a as a substitute for HFC-134a, the optimum load required for HC-600a was 0.050kgand 65% lower than HFC-134a. Bilen et al. [9] investigated theoretical analysis of the automobile air conditioning system using R152a, R22 and R12 to find out possible alternatives to R134a. From the results, they concluded that the performance does not change significantly by using R152a as compared with R134a. Bolaji et al. [10] made a performance comparison of low GWP refrigerants like R152a and HC600 theoretically, an alternative to HFC134a in a refrigerator. By observing these results, they concluded that R152a shows a higher volumetric cooling capacity (VCC) and co-efficient performance compared to HFC-134a. The average COPs achieved for HC-600a and HC-152a were 6% lower and 12.9% higher than HFC-134a. They concluded that HFC-152a shows the best results as compared with R134a. Morsi [11] performed a theoretical analysis of a VCR system using pure natural refrigerants to substitute HFC-134a. Results revealed that LPG gives a lower COP, and Isobutene gives a higher COP than HFC-134a by 11% and 5%, respectively.

Meng et al. [12] have done thermodynamic investigation for HFO-1234ze (E), R152a and HFO-1234ze (E)/R152a blends as a direct substitute to HFC-134a in a refrigerator system without making any modifications to the system. Sanchez et al. [13] led an experiment with low GWP refrigerants like HFO-1234yf, 1234ze (E), R290, R152a and HC-600a in the refrigeration system and experimental results were compared with HFC-134a. From that experiment, they concluded that HFO-1234yf and R152a have a perfect substitute for HFC-134a. Makhnatch et al. [14] examined the performance ofR450Awhich is a mixture of R134a/R1234ze (E) (42:58% by mass) as a substitute to HFC-134a in household refrigerators. It has been revealed that the Refrigerating effect and COP of the refrigerant mixture were approximately 10% and 3% lower than HFC-134a. At the same time, the outlet temperature of the compressor is more inferior to HFC-134a. Hasheer and Srinivas [15] conducted a theoretical investigation on low GWP refrigerants as a direct substitute to R134a in a domestic refrigerator. They concluded that R1234yf could be used as a natural substitute to R134a. Mohammad Hasheer Sk et al. [16] performed a thermodynamic analysis of low gwp refrigerant mixtures as alternative to R134a in refrigerator. From that they concluded that R290/600(60/40), ARM42, ARM42a, R440A, and R430A have better COP execution and volumetric cooling limit than R134a, which makes it the best substitute to R134a shows a favorable conditions.

A review of existing literature shows that much research has been done to find suitable alternative refrigerants from different groups individually. But the combination of two or more refrigerants from HC, HFC and HFO groups have not tried so far by the previous researchers. Also, the performance evaluation with LSHX was not done extensively. So the present work mainly focuses on filling that research gap. So the investigation was carried out with the refrigerants AC5, R440A and R430A. They are the combination of two or more refrigerants from the above-said groups. So the performance of a domestic refrigerator involving LSHX was evaluated with these three refrigerants, and the best alternative refrigerant to replace R134a have been identified and suggested.

2. ENVIRONMENTAL IMPACT OF ALTERNATIVE REFRIGERANT MIXTURES

Low GWP refrigerants can be categorized as pure Hydrofluorocarbons and Hydrofluoroolefins. Hydrofluoroolefins (HFO) is not new to chemistry. Like conventional Hydrofluorocarbons (HFCs), they are composed of hydrogen, fluorine and carbon. The only difference is that they are unsaturated, which means they have at least one double bond. Such molecules are called olefins or alkenes, so it is correct to name refrigerants such as HFC, HFA or HFO. The next name has become the most used name to refer to carbon-carbon double-bond refrigerants. Hydrofluoroolefins can be classified as HFO-1225, 1234 and 1243 isomers. Due to the flammability, the R1243 isomer is not used, and also, due to toxicity, the HFO-1225 isomer has not been developed. Therefore, the two possible alternatives in a household refrigeration system are HFO-1234yf and 1234ze (E). Another low GWP refrigerant is pure Hydrofluorocarbons, i.e. HFC152a, which has a very low GWP, value compared with HFC134a. HC (Hydrocarbons) are natural refrigerants that are R290 and R600a. These refrigerants have a GWP value of zero and exceptional properties in terms of efficiency and cooling effect.

The alternative refrigerants require not only protecting the ozone layer but also a lower GWP value. The low GWP refrigerants mixtures are R440A (R290/R134a/R152a in the ratio of 0.6:1.6:97.8 by mass, respectively), R430A (R152a/R600a 76:24in the ratio, by mass) and AC5 (R32/R152a/R1234ze (E) 12:5:83 in the ratio, by mass) were proposed in this document considered as substitutes for HFC-134a. The Thermo-physical and Environmental properties of above refrigerants are mentioned in the Table 1.

Table 1. Thermo-physical and Environmental properties of the refrigerants investigated

Properties	Refrigerants			
	R134a	**AC5**	**R440A**	**R430A**
Composition	-----	R32 (12%) R152a (5%) R1234ze (E) (83%)	R290 (0.6%) R134a (1.6%) R152a (97.8%)	R152a (76%) R600a (24%)
Molar mass (kg/kmol)	102	96.7	66.23	63.96
Critical temperature (°C)	101.01	103.2	112.66	106.98
Boiling point, BP (^{0}C)	- 26.1	-34.3 to -23.3	- 25.4	-27.6
Liquid density at 298 K (kg/m^3)	1206.7	1101.2	897.62	759.78
Vapor densityat 298K (kg/m^3)	32.35	28.92	18.68	19.69
ODP	0	0	0	0
GWP	1430	92	150	104

GWP value of the refrigerant mixtures can be calculated as follows:

$$GWP_{mixture} = GWP_p \times W_p + GWP_q \times W_q + GWP_r \times W_r$$

where, GWPp=GWP value of refrigerants p, GWPq= GWP value of refrigerant q, GWPr= GWP value of refrigerant r respectively; Wp, Wq and Wr are to be mass fraction of refrigerants p, q and r.

3. THERMODYNAMIC ANALYSIS OF REFRIGERANT MIXTURES

The thermodynamic Analysis of AC5, R440A and R430Aas a direct substitute to HFC-134a in a refrigeration system by varying the working conditions, i.e. when changing the temperature of the evaporator from -200°C to 100°C at different condenser temperatures. The complete analysis has been carried out by using an internal heat exchanger.

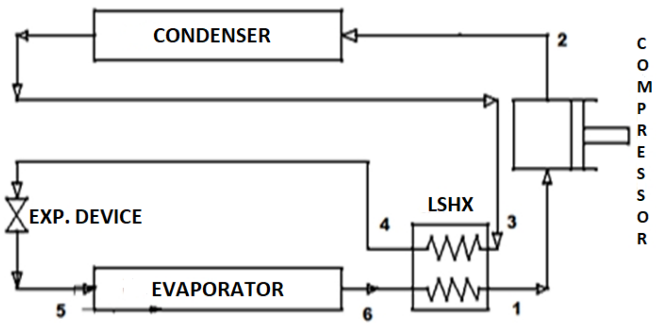

Figure 1. Refrigerator with LSHX

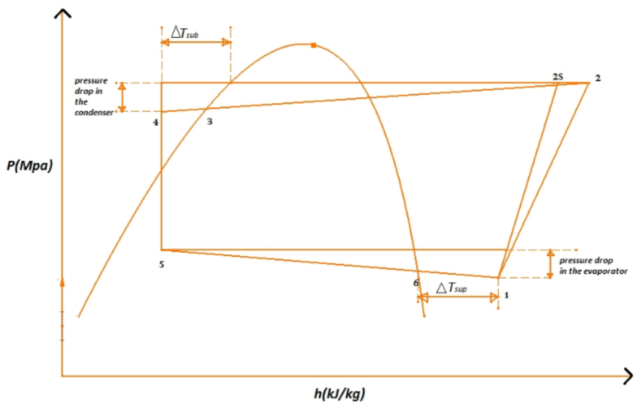

Figure 2. Pressure-enthalpy diagram of a refrigerator with LSHX

Data (from the literature review) used for analysis are given below. The results are plotted as shown in Figures 3 to 8.

1. Condensing temperatures: 40°C and 50°C
2. Evaporating temperatures: -20°C to 10°C
3. Loss of Pressure in the evaporator: 0.03 MPa
4. Loss of Pressure in the condenser: 0.02 MPa
5. Isentropic efficiency of a compressor: 0.70
6. Volumetric efficiency: 0.75
7. Compressor had a swept volume: 8.16cm^3/rev
8. Compressor Speed: 30rev/sec
9. Effectiveness of the heat exchanger: 0.6.

The components of a domestic refrigerator with LSHX in the position shown in Figure 1. The pressure-enthalpy diagram with the heat exchanger is shown in Figure 2. At the entry to the compressor, the refrigerant is in superheated condition, and pressure losses are considered. At the same time, it passes through the evaporator and condenser and is also represented in Figure 2. REFPROP 9.1 software is used to calculate the properties at each state, which is very accurate software for calculating properties.

Pressure ratio, volumetric cooling capacity, COP, outlet compressor temperature, Refrigeration effect and compressor power consumption is the main parameters to accept a direct substitute to a domestic refrigerator.

3.1 Performance parameters

The pressure ratio can be expressed as

$$r_p = P_{cond} / P_{evap\_act} \quad (1)$$

Compressor power consumption can be calculated from

$$\dot{W}_{comp} \quad \dot{m}_r (h_2 - h_1) \text{ kW} \quad (2)$$

Here h_1 & h_2 are the enthalpies of the refrigerant at entry and exit of the compressor. The relation between these two can be obtained by defining isentropic efficiency (η_{isen}) of the compressor as follows

$$Where \quad h_2 = h_1 + (h_{2s} - h_1) / \eta_{isen} \quad (3)$$

The refrigeration effect of a refrigerator can be calculated by

$$\text{Refrigeration effect, } Q_r = (h_1 - h_5) \quad kJ/kg \quad (4)$$

Here h_5 is the enthalpy of the refrigerant at the entry to the evaporator.

The cooling capacity of a refrigerator can be calculated by

$$\text{Cooling Capacity, } \dot{Q}_c = \dot{m}_r Q_r = \dot{m}_r (h_1 - h_5) \; kW \quad (5)$$

The Coefficient of Performance (COP) of the refrigerator is given by

$$COP = \frac{Cooling\ capacity}{Compressor\ power\ consumption} = \frac{\dot{m}_r (h_1 - h_5)}{\dot{m}_r (h_2 - h_1)} = \frac{(h_1 - h_5)}{(h_2 - h_1)} \quad (6)$$

The Volumetric Cooling Capacity (VCC) is given by

$$Q_{vol} = (h_1 - h_5) \times \eta_{vol} / v_1 \; kJ/ \quad (7)$$

Here η_{vol} is the volumetric efficiency of the compressor and v_1 is the specific volume of the refrigerant at the compressor inlet.

The mass flow rate of the refrigerant ($\dot{m}_r$) is given by

$$\dot{m}_r = V_s \times \rho_1 \times RPM \times \eta_{vol} / 60 \quad kg/s \quad (8)$$

4. RESULTS AND DISCUSSION

In the present work the performance of domestic refrigerator incorporated with LSHX was tested with different refrigerants AC5, R440A and R430A at two condenser temperatures of 40°C and 50°C with varying evaporator temperature from -20°C to 10°C. The results obtained from the theoretical analysis were mentioned in the Appendix and the important performance plots are drawn and discussed as below.

4.1 Variation of the mass flow rate of alternative refrigerants

Figure 3 depicts the mass flow rate of four refrigerants versus the temperature of the evaporator. Mass flow rate is the mass of refrigerant which pass per unit time. Mass flow rate is directly proportional to vapour density. Mass flow rate changes with change in evaporator temperature and do not vary with condenser temperature. For AC5, the mass flow rate is lower than R134a by 8.59% within an evaporator temperature range of -20°C to 10°C, respectively. For R440a, the mass flow rate is lower than HFC-134a by 30.18% within an evaporator temperature range of -20°C to 10°C, respectively. For R430a, the mass flow rate is lower than HFC-134a by 25.75% within an evaporator temperature range of -20°C to 10°C, respectively, due to low vapour density. Hence we can expect low power consumption with the above refrigerants as compared to R134a.

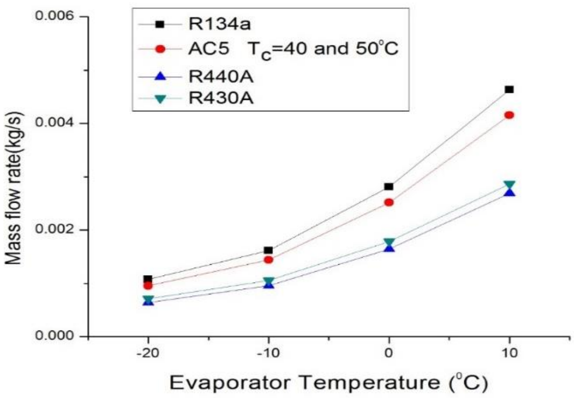

Figure 3. Refrigerant Mass flow rate (Kg/s) vs. Evaporator temperature (°C)

4.2 Pressure ratio variation

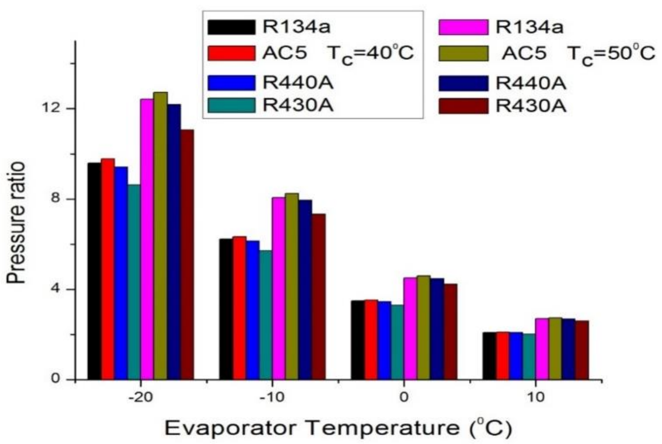

Figure 4. Pressure ratio vs Evaporator temperature (°C)

Figure 4 shows the graph between pressure ratios versus evaporator temperature. Pressure ratio is a ratio of higher pressure to lower pressure in VCR (vapour compression system). The pressure ratio is directly proportional to condenser temperature and inversely proportional to evaporator temperature. The results show that the pressure ratio of AC5 was higher than that of HFC-134a by approximately 1.13%, 1.48%, and 1.88%. At the same time, the pressure ratio of R440A and R430A lower than that of R134a by about 1.19%, 5.78%, respectively. Compressor volumetric efficiency compressor is influenced by pressure ratio. It is inversely proportional to volumetric efficiency, so from the above results, we observed that R440A and R430A have some percentage drop in pressure ratio compared to R134a. So we can expect excellent volumetric efficiency with these refrigerants.

4.3 Variation of volumetric cooling capacity

Figure 5 describes the deviation of VCC concerning the evaporator temperature for four different refrigerants. At a condenser temperature of 40°C and 50°C, it was obtained that the VCC of AC5 is lower than R134a by 9.91%, 10.10% and 10.35%, respectively, within an evaporator temperature range of -20°C to 10°C, respectively. VCC of R440A is lower than R134a by 6.4%, 5.1%, and 3.4%, respectively, within an evaporator temperature range of -20°C to 10°C. At 40°C and 50°C of condenser temperatures, R430a has a VCC lower than R134a by 1.12%, 0.41%, and higher by 0.44%, respectively, within an evaporator temperature range 20°C and 10°C. The capacity of volumetric cooling has a more significant influence on the size of the compressor. For replacement refrigerants, VCC can be maintained with a limit between -8% and 8% about HFC-134a. Due to a lower volumetric cooling capacity, AC5 Refrigerant is not advisable as it affects the compressor performance. Therefore, this refrigerant cannot be replaced as an alternative to HFC-134a. Consequently, considering that refrigerants R440A, R430A are suggested as a direct replacement of HFC-134a without alterations in the compressor.

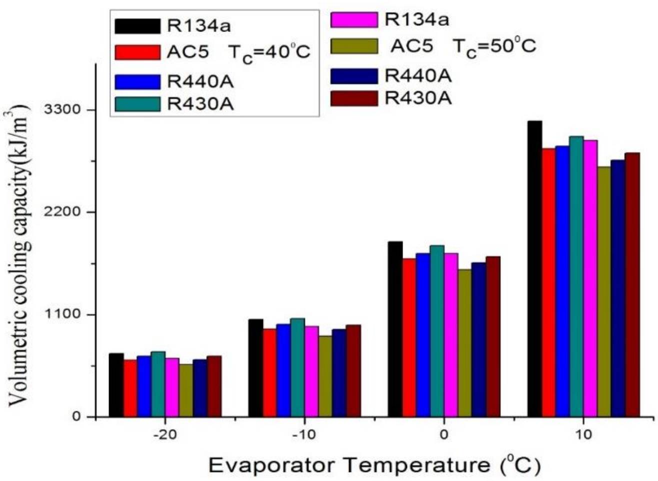

Figure 5. VCC vs Evaporator temperature (°C)

4.4 Variation of compressor power

The variation of compressor power versus evaporator temperature is shown in Figure 6. The average compressor power consumption of refrigerants AC5, R440a, R430a was lower than that of HFC-134a by about 4.1%, 7.6% and 1.4% respectively at condenser temperatures 40°C & 50°C. The energy consumption of a refrigerator compressor increases with the evaporator temperature due to the increase in the enthalpy difference between the output and the compressor inlet. This difference in enthalpy is due to the rise in the mass flow rate of the refrigerant.

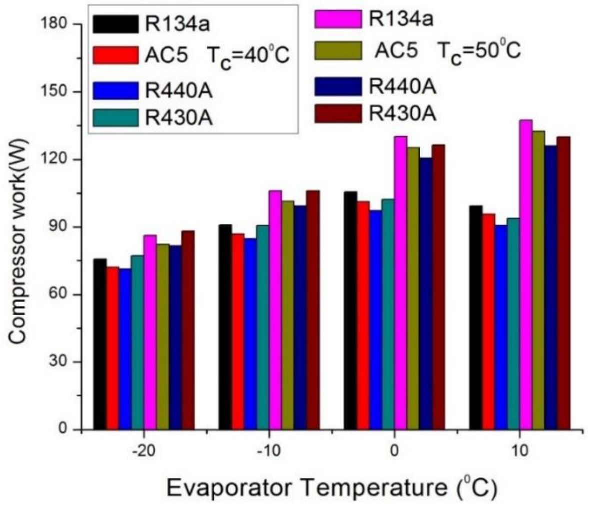

Figure 6. Compressor work (W) vs Evaporator temperature (°C)

4.5 Variation of COP

Figure 7 represents the deviation of COP of alternative refrigerants versus evaporator temperature. It was obtained that the average COP of R440A, R430A was higher than HFC-134a by approximately 1.37%, 2.7% at a condenser temperature 40C and higher than that of R134a 2.5%, 3.2%, respectively at a condenser temperature of 50°C. This is due to the lower power consumption of a refrigerator compressor. On the other hand, AC5 has a lower cop than R134a by approximately 6.58%, 5.6% at a condenser temperature of 40°C and 50°C.

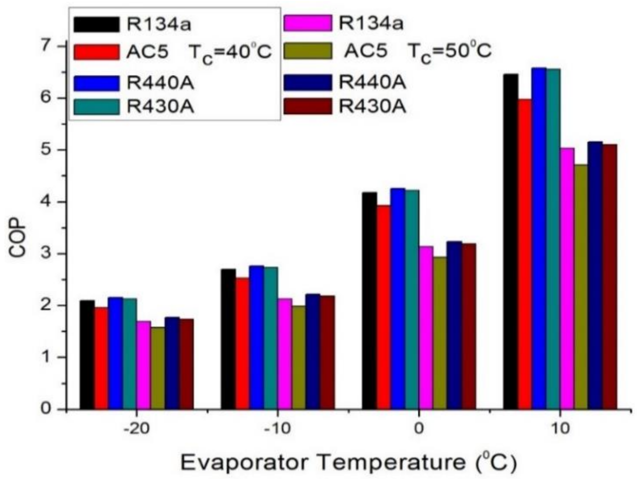

Figure 7. COP vs. Evaporator temperature (°C)

4.6 Variation of outlet temperature of compressor

The outlet temperature of the reciprocating refrigerant compressor versus evaporator temperature is shown in Figure 8 below. It was found that the average discharge temperature of compressor AC5, R440A and R430A was higher than that of HFC-134a of approximately 6-10°C, 3-7°C and 2-6°C at condenser temperatures of 40°C & 50°C. The higher outlet temperature affects the compressor motor coil and also affect the lubricant oil properties. Therefore, care must be taken when using this refrigerant as a direct substitute to HFC-134a in a refrigerator.

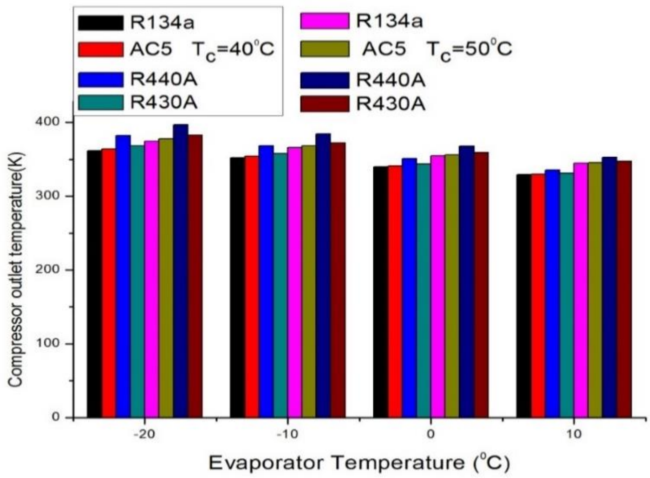

Figure 8. Compressor outlet temperature (K) vs. Evaporator temperature (°C)

5. CONCLUSIONS

The AC5 refrigerant shows a much lower volumetric cooling capacity compared to HFC-134a of approximately 9.1%. For a direct replacement, the value must be between -8% and 8%. Therefore, it is not suitable for direct use as a substitute for HFC-134a in a household refrigerator. R440A and R430A had given good results in VCC, power consumption of a compressor, COP and pressure ratio. But R440A shows a high compressor output temperature that affects the properties of lubricating oil for refrigerator compressor. When comparing all results with R134a, R430A can be used as a direct substitute for HFC-134a in the household refrigerator without changing the refrigerator. Therefore, it is concluded that R430A can be used as an alternative to HFC-134a in a household refrigerator. At the same time, when comparing the results with the literature (without LSHX) there is an improvement in the performance of a household refrigerator.

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NOMENCLATURE

COP	Coefficient of performance
GWP	Global warming potential
h	Specific enthalpy (kJ/kg)
LSHX	Liquid –suction heat exchanger
$\dot{m}$	Mass flow rate (kg/s)
Qvol	Volumetric Cooling Capacity (kJ/m^3)
$\dot{Q}_c$	Cooling capacity (kW)
Q r	Refrigeration effect (kJ/kg)
R	Refrigerant
rp	pressure ratio
v	Specific volume (m^3/kg)
Vs	Compressor displacement (m^3/rev)
$\dot{W}_{Comp}$	Compressor power consumption (kW)

Greek symbols

η	Efficiency (%)
ρ	Density (kg/m^3)

Subscripts

1, 2, 3,4,5,6	state points
Comp	compressor
Cond	condenser
evap_act	actual evaporator
isen	isentropic
Lshx	liquid suction heat exchanger
r	refrigerant
vol	volumetric

Acronym

CFC	Chlorofluorocarbons
HC	Hydrocarbons
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HFO	Hydrofluoroolefins
RPM	Revolutions per minute

APPENDIX

Theoretical results of different refrigerants investigated

CONDENSER TEMP =20℃					
Evaporator Temp (℃)	Parameter	R134a	AC5	R440a	R430a
-20	COP	2.723	2.5521	2.7922	2.7582
	T2	330.065	331.480	347.223	336.074
	Pr	7.2566	7.3811	7.1322	6.6142
	RE	163.995	146.565	158.465	169.485
	W	60.2248	57.4273	56.7522	61.4463
	mr	0.00107	0.00095	0.00063	0.00071
	Qvol	669.914	598.716	647.328	692.343
-10	COP	3.625	3.4029	3.6927	3.6619
	T2	324.551	325.613	337.831	329.122
	Pr	4.7068	4.7726	4.6501	4.3807
	RE	257.224	230.958	244.255	259.090
	W	70.9565	67.8699	66.144	70.7525
	mr	0.00161	0.00144	0.00095	0.00105
	Qvol	1050.75	943.456	997.774	1058.37
0	COP	6.129	5.7709	6.1894	6.1697
	T2	317.8262	318.4168	326.0162	320.5626
	Pr	2.6333	2.6578	2.6164	2.5197
	RE	474.2585	428.4571	439.8774	461.4826
	W	77.3791	74.2438	71.0685	74.7971
	mr	0.00281	0.002516	0.001646	0.001781
	Qvol	1937.33	1750.233	1796.885	1885.141
10	COP	13.7203	12.941	13.7439	13.7623
	T2	312.4305	312.6931	316.2469	313.6699
	Pr	1.5778	1.5853	1.57375	1.546
	RE	822.2744	746.8862	746.5463	776.1278
	W	59.9311	57.71468	54.3182	56.395
	mr	0.004631	0.004154	0.00269	0.002862
	Qvol	3358.964	3051.006	3049.617	3170.457
CONDENSER TEMP=40℃					
Evaporator Temp (℃)	Parameter	R134a	AC5	R440a	R430a
-20	COP	2.1509	2.007329	2.2407	2.1958
	T2	341.38	343.0975	360.4962	348.0223
	Pr	9.5808	9.7791	9.4043	8.6289
	RE	148.5438	132.3568	146.8354	155.2198
	W	69.05949	65.9367	65.5297	70.6885
	mr	0.001071	0.000954	0.000637	0.000713
	Qvol	606.7968	540.6732	599.8181	634.0681
-10	COP	2.7832	2.602066	2.8737	2.8298
	T2	336.1375	337.4736	351.4524	341.3648
	Pr	6.2143	6.32313	6.1314	5.7151
	RE	233.9562	209.5158	226.8553	238.0492
	W	84.0598	80.519	78.9397	84.1203
	mr	0.001613	0.00144	0.000953	0.001052
	Qvol	955.7038	855.8653	926.6964	972.4235
0	COP	4.3449	4.0743	4.4332	4.3937
	T2	329.7558	330.5883	340.0767	333.1769
	Pr	3.4767	3.52137	3.4499	3.2872
	RE	433.7212	391.0004	409.8254	425.8386
	W	99.822	95.9665	92.4435	96.9192
	mr	0.00281	0.002516	0.001646	0.001781
	Qvol	1771.737	1597.224	1674.124	1739.537
10	COP	7.8321	7.3536	7.9006	7.8727
	T2	324.648	325.1269	330.6743	326.595
	Pr	2.0832	2.1004	2.075	2.0169
	RE	755.4909	685.0454	697.4433	718.862
	W	96.46	93.15769	88.2767	91.3104
	mr	0.004631	0.004154	0.00269	0.002862
	Qvol	3086.156	2798.388	2849.033	2936.528
CONDENSER TEMP=50℃					
Evaporator Temp (℃)	Parameter	R134a	AC5	R440a	R430a
-20	COP	1.7149	1.5916	1.8266	1.7702
	T2	352.0495	354.1167	372.6777	359.1741

	Pr	12.4233	12.7302	12.1808	11.0684
	RE	132.6201	117.6973	134.8612	140.4975
	W	77.3331	73.948	73.8288	79.3646
	mr	0.001071	0.000954	0.000637	0.000713
	Qvol	541.749	480.7898	550.9037	573.9278
-10	COP	2.1799	2.02766	2.2951	2.238
	T2	347.1343	348.7888	364.0624	352.8692
	Pr	8.058	8.2313	7.9417	7.3309
	RE	209.977	187.3936	208.9412	216.3344
	W	96.321	92.4182	91.034	96.6602
	mr	0.001613	0.00144	0.000953	0.001051
	Qvol	857.7492	765.4971	853.518	883.7192
0	COP	3.2445	3.02757	3.3638	3.3068
	T2	341.162	342.2775	353.226	345.1232
	Pr	4.5082	4.584	4.4685	4.2165
	RE	391.9443	352.356	378.8852	389.0541
	W	120.8016	116.3821	112.6342	117.6506
	mr	0.00281	0.002516	0.001646	0.001781
	Qvol	1601.08	1439.363	1547.734	1589.274
10	COP	5.2585	4.9131	5.3759	5.3205
	T2	336.3926	337.1259	344.271	338.9059
	Pr	2.7012	2.7342	2.6877	2.5872
	RE	686.6651	621.2437	646.889	659.7641
	W	130.5816	126.4446	120.3311	124.0035
	mr	0.004631	0.004154	0.00269	0.002862
	Qvol	2805.005	2537.76	2642.521	2695.115