Hydrocarbon Refrigerant mixtures as an alternative to R134a in Domestic Refrigeration system: The state-of-the-art review

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Abstract-The objective of this paper is to present review on the alternative refrigerants used in the domestic refrigerators to have better performance with minimum losses. This paper give the summary and range of various refrigerants used in the domestic refrigerators. of global warming which affect the environment by the use of refrigerant, and our aim is to reduce the effect of global warming as well as optimize the performance of domestic refrigerators by using the latest refrigerants. This review paper represents the recent developments done in domestic refrigerator. Performance of refrigerator is increased by using different refrigerants. R134a is used in domestic refrigeration and other vapor compression system. R134a is having zero ozone depletion potential (ODP) and almost good thermodynamic properties, but it has a high Global Warming Potential (GWP) of 1300.The higher GWP due to R134a emissions from domestic refrigerators leads to identifying a long term alternative to meet the requirements of system performance, Therefore it is going to be banned very soon for environmental safety. Some new refrigerants is been found by researchers which are environmental friendly refrigerants having low GWP and low ODP. Hydrocarbon refrigerants particularly propane, butane and isobutene are proposed as an environment friendly refrigerants. After reviewing the various literatures on the hydrocarbons (R290 and R600a) refrigerants and their mixture gives good performance in small capacity domestic refrigerator to replace R134a.

Keywords: Hydro fluorocarbon refrigerant, GWP, ODP, Alternative refrigerants, Hydrocarbon refrigerants, Propane (R290), Isobutene (R600a).

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1 INTRODUCTION

Refrigerator is one of the home appliance utilizing mechanical vapor compression cycle in it process. The Vapor Compression Refrigeration Cycle is a process that cools an enclosed space to a temperature lower than the surroundings. To accomplish this, heat must be removed from the enclosed space and dissipated into the surroundings. However, heat tends to flow from an area of high temperature to that of a lower temperature. Figure (a) shows an ideal single-stage vapor compression refrigeration cycle in which compression occurs in the superheated region. Many investigators have reported that GWP of HFC refrigerants is more significant even though it has less than that of chlorofluorocarbons (CFC) refrigerants. HCFCs (hydro chlorofluorocarbons) and CFCs (chlorofluocarbons) have been applied extensively as refrigerants in air conditioning and refrigeration systems from 1930s as a result of their outstanding safety properties. However, due to harmful impact on ozone layer, by the year 1987 at Montreal Protocol it was decided to establish requirements that initiated the worldwide phase out of CFCs. By the year 1992, the Montreal Protocol was improved to found a schedule in order to phase out the HCFCs. Moreover in 1997 at Kyoto Protocol it was expressed that concentration of greenhouse gases in the atmosphere should be established in a level which is not intensifying global warming ozone layer. Subsequently it was decided to decrease global warming by reduction of greenhouse gases emissions.

2 ANALYSIS OF VAPOR COMPRESSION REFRIGERATION CYCLE

Figure 2 shows the refrigeration cycle on p-h diagram. The refrigerant evaporates entirely in the evaporator and produces the refrigerating effect. It is then extracted by the compressor at state point 1, compressor suction, and is compressed isentropic ally from state point 1 to 2. It is next condensed to liquid in the condenser, and the latent heat of condensation is rejected to the heat sink. The liquid refrigerant, at state point 3, flows through an expansion valve, which reduces it to the evaporating pressure. In the ideal vapor compression cycle, the throttling process at the expansion valve is the only irreversible process, usually indicated by a dotted line. Some of the liquid flashes into vapor and enters the evaporator at state point 4. The remaining liquid portion evaporates at the evaporating temperature, thus completing the cycle. Fig:1

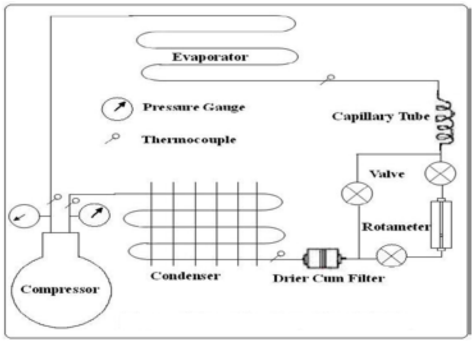

Fig1: Vapor compression refrigeration cycle

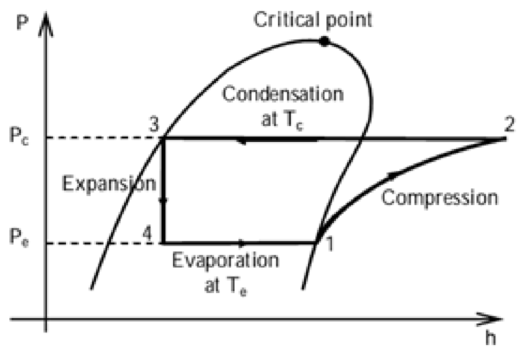

Fig2: p-h diagram Vapor compression refrigeration cycle

The refrigeration process that employed in the domestic refrigerator is based on a vapor compression cycle as shown in Figure 2.There are three main parameter that were considered in this study; compressor power, refrigeration capacity and coefficient of performance (COP)

Process line from 1 to 2 represents compressor power: Compressor power is defined as the power needed to do the compression process in watt. P= m (h2-h1) .... (1)

Process from point 2 to 3 represents heat rejection through condenser.

Qin= m (h1-h4) .... (2)

The coefficient of performance (COP): The COP of a domestic refrigerator is the ratio of the refrigeration capacity to the energy supplied to the compressor.

$$COP = \frac{\dot{Q}_{in}}{P} = \frac{\dot{m}(h_1 - h_4)}{\dot{m}(h_2 - h_1)}$$

3 History of Refrigerants

The working fluid used to transfer the heat from low temperature reservoir to high temperature reservoir is called refrigerant. There are different types of refrigerant which are dissuasion below.

3.1 CFC: They are molecules composed of carbon, chlorine and fluorine. It contributes to the destruction of the ozone layer. These are R11, R12, R113, R500, R502 etc.

3.**2 HCFC**: They are molecules composed of carbon, chlorine, fluorine and hydrogen. They are less stable than CFCs, destroy ozone and to a lesser extent. These are R22, R123, R124, R401a etc.

3.3 HFC: They are molecules composed of carbon, fluorine and hydrogen. They do not contain chlorine and therefore do not participate in the destruction of the ozone layer. But it has a high Global Warming Potential (GWP).

3.4 Hydrocarbons (HC): This is primarily propane (R290), butane (R600) and isobutene (R600a). These fluids have good thermodynamic properties, but are dangerous because of their flammability.

4 Need for Alternatives of R134a

4.1 Montreal Protocol

In 1987 Montreal protocol established the requirements that began the world – wide phase out of CFCs. Production of CFCs was phased out by the Montreal Protocol in developed countries in 1st of January, 1996. Production in developing countries was phased out in 2010. In 1992 Montreal protocol established the requirements that began the world – wide phase out of HCFCs. Complete production of HCFCs will be phased out by Montreal protocol in 2030.

4.2 Kyoto Protocol

Kyoto protocol aims at phasing out of substances that will lead to global warming.R134a is used in domestic refrigerator and other vapor compression systems as it was identified as a replacement to CFC-12, keeping in view its zero ozone depleting potential. R134a has 1300 global warming potential per 100 year, which is very high. The sale of R134a reported to AFEAS 1970-2003 is significantly increasing during the past two decades. The increased emission of R134a to the atmosphere are steadily increasing the concentration of greenhouse gases via leaks and mostly, in an indirect way, via energetic performance of refrigeration plant. This will lead to adverse climatic problem. Hence, R134a is one of the six chemicals in the “basket” that are to be phased out in the near future under Kyoto protocol.

4.3 Environmental Concern

The first major concern is depletion of ozone layer. Ozone layer is a layer which protects the earth from ultraviolet rays. Ozone depletion potential is evaluated on a scale that uses CFC-11 as a benchmark. All the other components are based on how damaging to the ozone they are in relation to CFC-11.The second major concern is global warming. Global warming is the increase in global earth surface temperature due to the absorption of infrared emission from earth surface. Global warming potential is evaluated on a scale that uses

ISSN 2229-5518

CO2 as the bench mark i.e. CO2 is assigned a value and other components are compared to CO2.

Hence, Kyoto protocol established the phased out of HFCs in the near future. Montreal and Kyoto protocols are interconnected, total climate change and ozone depletion depends on both the global warming potential and ozone depletion potential of the substances. Alternative to HFC refrigerants can be HC (Hydrocarbon) as there is no fluorine content. Hydrocarbons (HCs) are the class of natural occurring substances that include propane, pentane and butane. HCs are excellent refrigerants in many ways energy efficiency, critical point, solubility, transport, heat transfer properties and environmentally sound but their major concern is their flammability.

Thermodynamic Properties of various alternative refrigerants are given in Table 1.

Refrigerant	Chemical Formula	N.B.P	Molecular weight [g/mol]	Critical Temp. [°C]	Critical pressure [MPa]	Liquid density [kg/m3]
R134a	CH_2F CF_3	-26.15	102	101.1	4.059	511.9
butane (R600)	C_4H_{10}	-0.51	62.2	152	3.79	240.12
Propane(R290)	CH_3 - CH_2- CH_3	-42.1	44.096	96.68	4.247	218.5
Isobutene (R600a)	CH_3- CH- CH_3	-11.73	58.12	134.7	3.65	224.4
R290/R600a	45.2/ 54.8	-31.13	50.816	118.5	4.096	219.3
R290/R600a	50/50	-32.47	50.147	116.7	4.128	219.5
R290/R600a	54/46	-33.52	49.602	115.2	4.154	218.9
R290/R600a	56/44	-34.01	49.334	114.5	4.165	218.7
R290/R600a	60/40	-34.97	48.807	112.9	4.186	218.4
R290/R600a	68/32	-36.72	47.786	109.8	4.222	217.6

The variation of liquid densities against temperature it was observed that the liquid densities of all of the HCM and Pure HCs (R290 and R600a) refrigerants were found to be lower than that of R134a, as the liquid density is low it will significantly reduce the refrigerant charge requirement. Thus we can expect that if we will proceed with R290, R600a, and HCM it requires less charging amount as compare to that of the R134a. The other properties such as critical temperature, boiling point, molecular weight, ODP and GWP of R134a, R290, R600a and all of the HCM are compared in a above Table:1.

However, HCs show relatively high flammability, but the flammability of the mixture of R290 and R600a is not a problem in a small capacity refrigeration system with the refrigerant charge below 100g based on R134a. Very few changes are needed to a system and its components to be able to use HCs refrigerants. However, care is needed to ensure that flammability does not present safety problems:

- Systems using HCs must be designed so that leakage is not dangerous.
- During charging, appropriate equipment should be used to charge the systems, and the charging area has to be chosen with care
- Service technicians must be trained to handle HCs refrigerants safely.
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5. Advantages Of Hydrocarbons:

Hydrocarbons (HCs) are very good refrigerants for many reasons:

- They are compatible with copper and the standard mineral oils.
- They have a very low environmental impact in comparison with CFCs, HCFCs and HFCs.
- They perform very well, with good capacity and efficiency.
- Due to lower liquid densities, low refrigerant charge than that of HFCs then the high heat transfer coefficients hence high latent heat of vaporization.
- Coefficient performance (COP) of the system increases and Power consumption reduced with HCs.
- It improves compressor life due to low discharge temperature compare to HFCs, HCFCs and CFCs.

6. Literature Review

Lee, et al. [1] has investigate the performance of a small refrigerator is used for evaluated by using the mixture of R290 and R600a with mass fraction of 55:45 as an alternative to R134a. The compressor displacement volume of the alternative system with R290/R600a (55/45) was modified from that of the original system with R134a to match the refrigeration capacity. Both systems with R290/R600a (55/45) and R134awere tested, and then optimized by varying the refrigerant charge and capillary tube length under experimental conditions for both the pull down test and the power consumption test. The refrigerant charge of the optimizedR290/R600a system was approximately 50% of that of the optimized R134a system. The capillary tube lengths for each evaporator in the optimized R290/R600a system were 500mm longer than those in the optimized R134a system. The power consumption of the optimized R134a system was 12.3% higher than that of the optimized R290/R600a system. The cooling speed of the optimized R290/R600a (55/45) system at the in case setting temperature of 15^{0C}wasimproved by 28.8% over that of the optimized R134a system.

Jwo, and C.C. Ting. [2] Their investigation aims to apply the mixture of hydrocarbon refrigerants, R-290 and R-600a with each 50% component ratio, instead of the refrigerant R-134a for home refrigerators. During test the official R-134a refrigerant was replaced by varied mass hydrocarbon refrigerant, which was mixed by R-290 and R-600a with each 50% component ratio. The results show that refrigerating effect is improved by using hydrocarbon refrigerant. Moreover, the total power consumed is saved 4.4% and applied mass of refrigerant is reduced 40%.

Wongwises et al. [3] performed the theoretical study on traditional vapour compression refrigeration system with refrigerant mixtures based on HFC134a, HFC152a, HFC32, HC290, HC1270, HC600 and HC600a for various ratios and their results are compared with CFC12, CFC22 and CFC134a as possible alternative replacement.

Considering the comparison of coefficient of performance (COP) and pressure ratio of tested refrigerants and also the main environmental impacts of ozone layer depletion and global warming, refrigerant blends of HC290 (40%) + HC600a (60%) and HC290 (20%)+HC1270 (80%) are found to be the most suitable alternatives among refrigerants tested for R12 and R22 respectively. The refrigeration efficiency, coefficient of performance (COP) of the system increases with increasing evaporating temperature for a constant condensing temperature. Similarly Hc22a can be tested for R-134a

Sattar et al. [5] designed a domestic refrigerator to work with R-134a and was used as test unit to determine the possibility of using hydrocarbons and their blends as refrigerants. Pure butane, isobutene and mixture of propane, butane and isobutene were used as refrigerants. The performance of refrigerator using hydrocarbons as refrigerants was investigated and compared with the performance of refrigerator when R-134a was used as a refrigerant. In this experiment effect of condenser temperature and evaporator temperature on COP, refrigerating effect. Condenser duty, work of compression and heat rejection ratio were investigated. After successful investigation on the performance of hydrocarbon and blends of hydrocarbon refrigerants it is found that COP of the system is comparable to R-134a and also energy consumption is similar to R-134a. This suggests that blends of hydrocarbon can be used as an alternative to R-134a

Mahmood Mastani Joybariet al. [6] in this analysis the performance of a domestic refrigerator originally manufactured to use 145 g of R134a. It was found that the highest exergy destruction occurred in the compressor followed by the condenser, capillary tube, evaporator, and superheating coil. Taguchi method was applied to design experiments to minimize exergy destruction while using R600a.Taguchi parameters were selected by the obtained results from R134a and an experiment using 60 g of R600a, which indicated similar results as R134a. Based on the outcomes, R600a charge amount, condenser fan rotational velocity and compressor coefficient of performance were selected for the design. The analysis of variance results indicated that R600a charge amount was the most effective parameter. At the optimum condition, the amount of charge required for R600a was 50 g,66% lower than R134a one, which not only brings economic advantages, but also significantly reduces the risk of flammability of the hydrocarbon refrigerant.

Tiwari et al. [7] performed an analysis on vapour compression refrigeration system by using four ozone friendly hydro-fluorocarbon HFC refrigerants R125, R134a, R143a and R152a to replace R-12. The experiment was done to evaluate the coefficient of performance (COP), refrigerating capacity (RC) and compressor work at various evaporating and condensing temperature.

Among all the tested refrigerants R152 has higher coefficient of performance (COP), higher refrigerating capacity than R12, while R134a has a slightly lower COP and higher refrigerating capacity than R12. On the basis of this study HC22a which is also an eco-friendly refrigerant can be evaluated for its COP and refrigerating capacity.

Austin et al. [8] had presented the study on refrigerator using mixed refrigerants. The Mixed Refrigerants (hydrocarbons mixtures propane, and isobutene) and compared with the performance of refrigerator with R-134a was used as refrigerant. The effect of condenser temperature and evaporator temperature on COP, refrigerating effect was investigated. The energy consumption of the refrigerator during experiment with mixed refrigerants and R-134a was measured.

Rasti et al. [9] devoted his work to feasibility study of substitution of two hydrocarbon refrigerants instead of R134a in a domestic refrigerator. The effect of parameters including refrigerant type, refrigerant charge and compressor type are investigated. This research is conducted using R436A (mixture of 46% iso-butane and 54% propane) and R600a (pure iso-butane) as hydrocarbon refrigerants, HFC type compressor (designed for R134a) and HC type compressor (designed for R600a).

Chavhan et al. [10] have presented the study on refrigerator using R134a. R134a is having zero ozone depletion potential (ODP) and almost same thermodynamic properties as R12, but it has a high Global Warming Potential (GWP) of 1300.Hence an alternative for this refrigerant is to be identified. Paper reviews the performance of different environmental friendly refrigerants and their mixtures in different proportions and also observed the effect of working parameters like dimensions of capillary tube, working pressures and working temperatures, which affect the coefficient of performance (COP) of vapor compression refrigeration system.

Gurumurthy et al.[11] had discussed on experimental studies carried out for the performance evaluations of a domestic refrigerator when four ratios of hydrocarbon, propane, butane and isobutene are used as possible alternative replacements to the traditional, R-12 refrigerant. The uses of proposed alternative refrigerants have the advantages such as (i) availability in local places, (ii) cheapness, and (iii) of an environmentally friendly nature. An unmodified R – 12 domestic refrigerators and air conditioners were charged and tested with each of the four hydrocarbon mixtures containing.

Bolaji et al.[12]provided comparative experimental steady is carried out of there refrigerator R-152a R-32 & R-134a to replace R-134a R-152a & R-32 are new refrigerant having zero ODP & GWP finally, he considered that Cop of R-152a 4.7% higher than R-134a & Cop of R-32 is 8.5% less than R- 134a. Pull down time is achieved early than R-32. Power is considerably reduced with R-152a than the R-32 R-134a.

Mani et al. [13], have analyzed a vapor compression refrigeration system with the new R290/R600a refrigerant mixture as drop-in replacement was conducted and compared with R12 and R134a. The VCRS was initially designed to operate with R12.The results showed that the refrigerant R134a showed slightly lower COP than R12. The discharge temperature and

Mohanraj et al [14] in the present work, an experimental investigation has been made with hydrocarbon refrigerant mixture (composed of R290 and R600a in the ratio of 45.2:54.8 by weight) as an alternative to R134a in a 200 l single evaporator domestic refrigerator. Continuous running tests were performed under different ambient temperatures (24, 28, 32, 38 and 430C), while cycling running (ON/OFF) tests were carried out only at 32 ◦C ambient temperature. The results showed that the hydrocarbon mixture has lower values of energy consumption; pull down time and ON time ratio by about 11.1%, 11.6% and 13.2%, respectively, with 3.25–3.6% higher coefficient of performance(COP). The discharge temperature of hydrocarbon mixture was found to be 8.5 to 13.4 K lower than that of R134a. The overall performance has proved that the above hydrocarbon refrigerant mixture could be the best long term alternative to phase out R134a.discharge pressure of the R290/R600a mixture was very close to R12. The R290/R600a (68/32 by wt %) mixture can be considered as a drop-in replacement refrigerant for R12 and R134a.

C.C Yu and T.P Ting [15] the charged ratios were 30%, 40%, 50%, and 60% based on the charged mass ofR134a for HC refrigerants. The results of the no-load pull-down test revealed that the optimal charged mass for all the HC refrigerants was 40% of that of R134a. the capillary tube lengths of R134a, HC1, HC2, and HC3 were recalculated to be 2.77, 5.05, 5.34, and 5.60 m, respectively, and the recalculated capillary tube was used in the 24-hour on load cycling test. The results of the 24-hour on-load cycling test showed that the freezer temperatures considerably decreased when the HC refrigerants were used, and that all of the HC refrigerants could be used in the R134arefrigerator after changing the capillary tube lengths.

Mahajan and S.A. Borikar [16] conclude that the performance of HC-12a (mixture of R290/R600a (60/40) % by wt.) in the domestic refrigerator was constantly better than those of R134a throughout all the operating conditions, which shows that HC-12a can be used as replacement for R134a in domestic refrigerator.

Rasti1 et al [17] have presents the feasibility study of using hydrocarbons mixture as substitutes for R134a in a domestic refrigerator. A domestic R134a type refrigerator was filled with R436a that is a mixture of Propane and isobutane (with 56 % wt of Propane) and turned on in a test room. Meanwhile the temperatures at various locations in the domestic refrigerator, consumed energy, compressor power and pressure at suction and discharge of the compressor had been recorded. The experiments were repeated for different surrounding temperatures at a fixed relative humidity. Experiments had been done for a same R134a refrigerator, and results for both refrigerants were compared. Also the effect of injected amount of R436a has been studied in this work. The results showed that R436a can be considered as a convenient alternative for R134aprovided the optimum conditions can be determined.

Balakrishnan.P1 et al[18] in this this paper the author explores an experimental investigation of an alternative eco-friendly refrigerant for R134a with a better Coefficient Of Performance (COP), reduced Global Warming Potential (GWP) and Ozone Depletion Potential(ODP). This investigation has been accessed using a hydrocarbon refrigerant mixture composing ofR32/R600a/R290 in the ratio of 70:5:25 by weight. The performance characteristics of the domestic refrigerator were predicted using continuous running tests under different ambient temperatures and cyclic running (On/Off) tests at the fixed temperatures i.e., evaporation temperature (-5˚C) and condensation temperature (30˚C). The obtained results showed that the hydrocarbon mixture has lower values of energy consumption; pull down time and ON time ratio also higher Coefficient of Performance (COP). Thus, the performance of the alternate refrigerant derives the better choice than R134a.

Sattar, et al[19] in this paper the performance of the refrigerator using hydrocarbons as refrigerants was investigated and compared with the performance of refrigerator when R-134a was used as refrigerant. The effect of condenser temperature and evaporator temperature on COP, refrigerating effect, condenser duty, work of compression and heat rejection ratio were investigated. The energy consumption of the refrigerator during experiment with hydrocarbons and R-134a was measured. The results show that the compressor consumed 3% and 2% less energy than that of HFC-134a at 28°C ambient temperature when iso-butane and butane was used as refrigerants respectively. The energy consumption and COP of hydrocarbons and their blends shows that hydrocarbon can be used as refrigerant in the domestic refrigerator. The COP and other result obtained in this experiment show a positive indication of using HC as refrigerants in domestic refrigerator.

Natarajan and S. Vanitha [20] an attempt has been made to investigate the performance of the Joule–Thomson refrigeration system with the addition of a heat exchanger in between the condenser and the expansion device. In order to study the performance of the system experimentally, a Joule-Thomson refrigeration system experimental setup has been developed with mixture of R290/R600a (40/60, 50/50, 60/40 and 70/30 by weight) are used as environmental friendly refrigerant mixtures and experiments are conducted. The effect of evaporator temperature on the coefficient of performance, exergy efficiency and exergy destruction ratio of the J-T system are investigated. The Joule–Thomson refrigeration system with compact heat exchanger yields higher coefficient of performance by 10.45% and exergy efficiency obtained by 4.25%.

Deepak Paliwal, S.P.S.Rajput [21] have suggested to retrofit the system with new alternative refrigerants. Presently in market some hydrocarbon mixtures and pure hydrocarbons are available to replace R134a. But what will be the ratio and mass fraction to be used for better and safe performance of the system. This investigation focuses on mixture ratio of pure hydrocarbon R290 and R600a uses in 200 liter domestic refrigeration system by certain changes in condenser and capillary. The outcome of this work is 80g mixture of R600a/R290 (60/40 by wt%) give better performance than 80g mixture of R600a/R290 (70/30 by wt%). COP of R600a/R290 (60/40 by wt%) mixture is higher in the range 22%-26.3% than mixture R600a/R290 (70/30 by wt%) for capillary of 3.5m length and 0.036 inches diameter. During the experiments it is found that 0.036 inches dia. capillary is more suitable as expansion device than 0.031 inches dia. capillary at all length . It is also find out that by increasing the length of capillary in the system hydrocarbon mixture give better results. The R600a/R290 (60/40 by wt%) mixture can be consider as a drop- in replacement refrigerant for HFC134a.

B. Baskaran and P. Koshy Mathews [22] performed an analysis on vapour compression refrigeration system with various eco-friendly refrigerants of HFC-152a, HFC-32, HC-290, HC-1270, HC-600a and RE-170.Considering the comparison of performance coefficient (COP) and pressure ratio of the tested refrigerants and also the main environmental impacts of ozone layer depletion and global warming, refrigerant RE-170 was found to be most suitable alternative among refrigerant tested for R-134a. The performance coefficient of the system increases with increase in evaporating temperature for constant condensing temperature.

7. CONCLUSIONS

From the above literature survey it is found that, the several refrigerants are expelled due to their environmental impact, are expected to be replaced.

Few researchers have reported on combination of different refrigerants in refrigeration system. Hence it is clear that there is wide scope to do the research in the study on different types of refrigerants used to improve performance of domestic refrigerator.

The Following conclusions were observed from this review paper:

- R134a is a HFC refrigerant and it contributes to global warming because of fluorine content in it. Ozone depletion and total climate change depends on both global warming potential and ozone depletion potential. So, there is a need to find out alternatives of R134a under Kyoto protocol and Montreal protocol.
- From literature review and properties of refrigerant R32, R152a, R125, R413A (mixture of 88% R134a, 9%R218, 3%R600a), R290/R600a (68/32 by wt. %), R290/R 600a (40/60 by wt. %) and R123/R290 (mixture of 70/30) are identified as alternatives of R134a.

- There is a need of comparing the alternative refrigerants from thermodynamic, thermo economic, environmental, toxicity, stability and flammability point of view. So, that best alternative to R134a can be found out.
- There is a need of further research to be done on the different mixtures of HFCs and HCs, to find the alternatives of R134a.
- According to Montreal and Kyoto protocols R600a, R290 and blends of R290 and R600a are the better option for the replacement of R134a in domestic refrigerator, due to their low global worming potential (GWP) and zero ozone depletion potential(ODP).

8. Nomenclature

Symbol	Meaning
COP	Coefficient of performance
GWP	Global warming potential
ODP	Ozone depletion potential
GHG	Greenhouse gas
CFC	Chlorofluorocarbon
HCFC	Hydro Chlorofluorocarbon
HFC	Hydro fluorocarbon
R11	Trichlorofluoromethane
R12	Dichlorodifluoromethane
R22	Monochlorodifluoromethane
R32	Methylene Fluoride
R125	Pentafluoroethane
R134a	Tetrafluoroethane
R152a	Difluoroethane
R290	Propane
R600	Butane
R600a	isobutene

References

[1] M.Y. Lee, D.Y. Lee, Y. Kim, "Performance characteristics of a small-capacity direct cool refrigerator using R290/R600a(55/45)," International journal of Refrigeration, no. 31, pp. 734 741, 2008

[2] C.S Jwo, C.C. Ting, "Efficiency analysis of home refrigerators by replacing hydrocarbon refrigerants," Measurement, no. 42, pp. 697-701, 2009.

[3] S. Wongwises, N. Chimres, "Experimental study of hydrocarbon mixtures to replace HFC-134a in a domestic refrigerator," Energy converse. Manage., no. 46, pp. 85-100, 2005.

[4] Dongsoo Jung, Kim, Kilhong, "Testing of propane/isobutene mixture in domestic Refrigerators", International Journal of Refrigeration 23 (2000) 517-527.

[5] Sattar MA, Saidur R, and Masjuki H.H, "Experimental Investigation on the Performance of Domestic Refrigerator Using Isobutene and Mixture of Propane, Butane and Isobutene" 1st International Conference of the IET Brunei Darussalam Network, (26-27 May 2008)1-10.

[6] Mahmood Mastani Joybari, Mohammad Sadegh Hatamipour, Amir Rahimi, Fatemeh Ghadiri Modarres "Exergy analysis and optimization of R600a as a replacement of R134a in a domestic refrigerator system", international journal of refrigeration 36(2013) 1233-1242

[7] Dr. A. C. Tiwari, Shyam Kumar Barode, "Performance analysis of vapour compression refrigeration system using hydro fluorocarbon refrigerants", International Journal of Scientific and Engineering Research, Volume 3, Issue 12, ISSN: 2229-5518, 2012.

[8] N.Austin,Dr.P.SenthilKumar,N.Kanthavelkumaran, Thermodynamic Optimization of Household Refrigerator Using Propane –Butane as Mixed Refrigerant", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 2, Issue 6, (November-December 2012), 268-271.

[9] Mehdi Rasti, Aghamiri, Mohammad-Sadegh, " Energy efficiency enhancement of a Domestic refrigerator using R436A and R600a as alternative refrigerants to R134a",International Journal of Thermal Sciences 74 (2013) 86-94

[10] SandipP.Chavhan, Prof.S.D.Mahajan, "A Review of an Alternative to R134aRefrigerant in Domestic Refrigerator", International Journal of Emerging Technology and Advanced Engineering (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 9), (September2013) 550-556.

[11] Gurumurthy VijayanIyer, "Experimental Investigations on Eco-Friendly Refrigeration and Air Conditioning Systems" Proceedings of the 4th WSEAS International Conference on Fluid Mechanics and Aerodynamics, Elounda, Greece, (August 21-23, 2006), 445-450.

[12] B.O.Bolaji, University of agriculture, Nigeria."Exegetic performance of a domestic refrigerator using R-12 and its alternative refrigerants" Journal of Engineering Science and Technology Vol. 5, No. 4 (2010) 435 - 446 © School of Engineering, Taylor's University.

[13] K. Mani, and V. Selladurai, "Experimental analysis of a new refrigerant mixture as drop-in replacement for CFC12 and HFC134a" International Journal of Thermal Sciences 47, 2008. pp. 1490–1495.

[14] M. Mohanraj, S. Jayaraj, C. Muraleedharan, P. Chandrasekar, "Experimental investigation of R290/R600a mixture as an alternative to R134a in a domestic refrigerator," International Journal of Thermal Sciences, no. 48, pp. 1036-1042, 2009.

[15] Chao-Chieh Yu, Tun-Ping Teng, "Retrofit assessment of refrigerator using hydrocarbon refrigerants," Applied Thermal Engineering, no. 66, pp.507-518, 2014.

[16] R.Y. Mahajan, S.A. Borikar , "Performance evaluation of domestic refrigerator using HC-12a refrigerant as an alternative to R12 and R134a,"Internaational Journal of Engineering and Science, vol. 3, no. 10, pp. 26-37, 2014.

[17] M. Rasti1, S.F. Aghamiri1, M.S. Hatamipour1, M. Tavakoli2, "Feasibility of using hydrocarbon mixture (R436a) as refrigerant in domestic refrigerators"13th Iranian National Chemical Engineering Congress & 1st International Regional Chemical and Petroleum Engineering Kermanshah, Iran, 25-28 October, 2010.

[18 Balakrishnan.P, Dr.K.Karuppasamy, Ramkumar.J, Anu Nair, "Experimental Study of Alternative Refrigerants To Replace R134a In A Domestic Refrigerator" International Journal Of Research In Aeronautical And Mechanical Engineering ISSN (Online): 2321-3051 Vol.3 Issue.4, April 2015. Pgs: 28-35.

[19] M. A. Sattar, R. Saidur and H. H. Masjuki "Performance Investigation of Domestic Refrigerator Using Pure Hydrocarbons

and Blends of Hydrocarbons as Refrigerants" World Academy of Science, Engineering and Technology 5 2007.

[20] V. Natarajan1 and S. Vanitha "Performance Investigation of Joule–Thomson Refrigeration System with Environment Friendly Refrigerant Mixtures" Indian Journal of Science and Technology, Vol 8(S9), 465–473, May 2015, ISSN (Print): 0974-6846 ISSN, (Online) : 0974-5645

[21] Deepak Paliwal, S.P.S.Rajput "Experimental Analysis of Hydrocarbon Mixtures As The New Refrigerant In Domestic Refrigeration System" International Journal of Scientific & Engineering Research, Volume 6, Issue 6, June-2015 623 ISSN 2229-5518

[22] Baskaran A., Mathews P. K., "A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential", International Journal of Scientific and Research Publications, Volume 2, Issue 9, ISSN 2250-3153, pp: 1-8, September 2012.