IN DOMESTIC REFRIGERATOR INVESTIGATE THE PERFORMANCE BY USING R440A AND R429A AS AN ALTERNATIVE TO 134A

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Abstract: R134a is widely used and considered as an environmentally safe refrigerant and more suitable refrigerant for domestic refrigerators. It is safer to ozone layer but it has a high GWP (Global Warming Potential). The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) asked for reduction in emission of six categories of greenhouse gases, including R134a, used as refrigerant in domestic refrigerators. Therefore, according to Kyoto protocol the consumption of R134a must be seriously reduced. From the environmental and ecological points of view, it is urgent to find some better substitutes for high global warming refrigerant. The European Union Regulations section 517 of 2014 has been recently approved in a further attempt to curb the effects of global warming. As a consequence, the refrigerants manufacturing sector is moving towards alternative refrigerants with a low Global Warming Potential (GWP) in accordance with the limit fixed by these regulations (150). Many researchers tested hydrocarbons refrigerant mixtures as alternatives to R134a in domestic refrigerators due to its good thermodynamic and thermo-physical properties compared to R134a. However, HC refrigerants have their own drawbacks with respect to flammability and temperature glide. Another possible alternative to R134a in domestic refrigerators is R440A, with low GWP of 144. The refrigerant mixture composed of R440A and R600a in the ratio of 76:24, by mass has been developed and designated as R429A by ASHRAE. It is a near azeotropic with temperature glide of 0.2°C and low GWP of 107 and considered as a viable alternative to R134a.

In this research work, the performance of the domestic refrigeration system with the following refrigerants has been investigated experimentally as a retrofit for R134a.

1. R440A which is a mixture of R-290/134a/152a (.6±.1/1.6±.6/97.8±.5) - ODP = 0, GWP = 144.
2. R429A which is a mixture of R-E170/152a/600a (60±1/10±1/30±1) ODP = 0, GWP = 13.9

R440A and R429A by using CYCLE_D Software to predict the different performance characters. The experimental investigations were carried out in a domestic refrigerator of Kelvinator make with 169 liter capacity which was originally manufactured to work with R134a. This refrigerator was equipped with necessary sensors and instrumentations for experimental investigations. The results of the present investigation have proved that the selected alternative refrigerants R440A, R429A are the excellent substitutes for R134a. In conclusion, the proposed refrigerants seem to be a long term refrigerant to replace R134a from the viewpoint of eco-friendly refrigerants with zero ODP and low GWP values. It also has better performance than R134a requiring minimal changes in the existing refrigerators. contains**.**

***Keywords* - R114, R600a, R236fa, COP, R429A, GWP**

1. INTRODUCTION

Hydro chlorofluorocarbons (HCFCs) and chlorofluocarbons (CFCs) are used widely 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 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. Also in 1997 at Kyoto, 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 in the usage of greenhouse gases emissions. (Granryd et al. 2005)

As a consequence of this protocol, even newly developed HFCs refrigerants like R-134a should be gradually phased out due to their high global warming potentials. Hence in order to meet the global ecological goals, conventional refrigerants should be replaced by more environmental friendly and safe refrigerants such a way the energy efficiency also is improved. Some of the refrigerants used are discussed below.

1.2 R134A REFRIGERANT

In the past decade, R12 has been replaced by R134a in refrigerating appliances due to its high ODP and GWP. At present in India more than 80% of the refrigerating systems are working with R134a.The GWP of HFCs is not as high as CFCs, but they are significantly higher than the natural refrigerants such as hydrocarbons and ammonia. The international treaty, Kyoto Protocol, between developed nations seeks to reduce emissions of carbon dioxide and five other Green House Gases (GHGs), of which HFCs are one among them (Mohanraj et al. 2008). R134a possesses favorable characteristics such as zero ODP, non-flammability, stability and similar vapour pressure to that of R12. Earlier studies indicate that the energy efficiency of R134a obtained in actual refrigerators was lower than that of R12 (Qiyu Chen et al. 1999).

1.3 HYDROCARBON REFRIGERANTS

HC refrigerants are simple compounds containing carbon and hydrogen and do not contain any halogens like chlorine, fluorine etc. These refrigerants are non-toxic but highly inflammable and have zero ODP and negligible GWP. HC refrigerants are completely miscible with commonly used mineral oils as well as PAG and POE (Agarwal, 1998). Since last couple of years hydrocarbons are being used as alternative refrigerants to R12 and R134a due to their excellent thermo physical properties. But pure hydrocarbons are not suitable for drop in replacement for existing systems due to mismatch of its saturation properties. It demands changes in the design, especially compressor (Suresh Bhata Sherstha et al. 2001). The use of hydrocarbons was restricted due to its flammable properties.

1.4 R440A (HFC REFRIGERANT)

R440A is the mixture composed of R-290/134a/152a in the ratio of 0.6/1.6/97.8 is the only HFC refrigerant that still can be considered as an alternative for R134a in refrigeration systems. While its GWP is about 144, its chemical properties are like those of R134a, thus it could be used in existing production system with just some small changes. R440A has 10% of GWP compared to R134a with lesser amount of refrigerant charge compared to R134a.In the other words with R440A as working fluid, refrigerant charge is about 35% lower than that of R134a. Due to its larger molecules in comparison with R134a, R440A has less refrigerant leakage. It has been proposed as a “drop-in” replacement for R-134a. (Mathur, 2003) R440A is mildly flammable. One way to decrease the flammability risk is to reduce the refrigerant charge in the system. Hence R440A can be detained in a compact refrigeration system in order to decrease its risk of flammability.

1.5 REFRIGERANT MIXTURE R429A

The mixture composed of E170/152a/600a in the ratio of 43/24/24, by mass has been developed and designated as R429A by ASHRAE. It is a near azeotropic with temperature glide of 0.2°C and low GWP of 13.9 and considered as a viable alternative to R134a Park & Jung (2009) studied the Performance of domestic water purifiers working with R134a and R429A. It has been reported that R429A is a good energy efficient and environment friendly mixture to replace R134a. Naturally occurring substances such as water, carbon dioxide, ammonia and hydrocarbons are believed to be environmentally safe refrigerants. In India CFCs phase out was successfully implemented by replacing R12 with R134a. But this R134a should also be phased out due to relatively high GWP. So, research towards environmentally safe refrigerants is growing. At the same time the performance of the refrigerants and their flammability are other crucial factors that have to be taken into account while selecting the refrigerants. Further, it is desirable that the designed refrigerants, replace the current refrigerants without any major change in the system accessories. A trade-off point between all these factors has been considered while proposing the alternative refrigerants in the present work.

sk as measured by β. But on the other side some empirical results showed that high risk is not associated with high return (Michailidis et al. 2006, Hanif, 2009). Mollah and Jamil (2003) suggested thatrisk-return relationship is notlinear perhaps due to high volatility.

4. LITERATURE REVIEW

Dalkilic & Wongwises (2010) made a performance comparison of vapour compression refrigeration system using various alternative refrigerants. A theoretical performance study on a traditional vapour compression refrigeration system with refrigerant mixtures based on HFC134a, HFC152a, HFC32, HC290, HC1270, HC600, and H600a was done for various ratios and their results are compared with CFC12, CFC22 and HFC134a as possible alternative replacements.

Bolaji et al. (2010) conducted an experimental study with domestic refrigerator to investigate the performance of R440A and R32 as alternative to R134a. The results obtained showed that the design temperature and pull down time set by International Standard Organization (ISO) for small refrigerator were achieved earlier using refrigerant R440A and R134a than using R32.

Dongsoo Jung et al. (2000) have assessed the performance of a binary mixture R290/R600a mixture for domestic refrigerator. Theoretical analysis indicated that at 0.2 to 0.6 mass fraction of R290 of the considered mixture yields an increase in the COP of up to 2.3% as compared to R12. For the actual tests, two commercial refrigerators of 465 and 295 liters capacity were used. For the tests with the alternative refrigerants, the hardware remains same, except the length of the capillary and quantity of charge. For each unit, both the energy consumption test and the pulldown test were conducted under the similar operating condition.

Suresh Bhakta Shrestha et al. (2001) have studied the performance of R290 and R600a mixtures in VCR systems for heating and sim ultaneous heating and cooling applications in comparison with R134a, R114 and R236ea. R290 offers a large pressure difference usually more than 18 bar, an allowable limit for reciprocating compressors. It offers discharge temperature comparable with that of R134a. R290 is not suitable for high temperature heat pumps because of its lower critical temperature. R290 is not suitable to retrofit into systems designed for R134a and R236ea. Pure R600a is also not suitable for retrofit condition due to its high pressure ratios. At 50%R290/50%R600a has favorable pressure chrematistics which can be used as drop in replacement for R134a.

Somchai Wongwises et al. (2005) have conducted experiments to substitute R134a in a domestic refrigerator with hydrocarbon mixtures of R290, R600 and R600a. A 239liter capacity refrigerator initially designed to work with R134a was chosen for the experimentation. The pressure and temperature at the entry and exit of the compressor and compressor power readings were taken for the analysis. The alternative refrigerant mixtures used are divided into three groups: the mixture of three hydrocarbons, the mixture of two hydrocarbons along with R134a and the mixture of two hydrocarbons.

Somchai Wongwises et al. (2006) have experimentally investigated the performance of hydrocarbon mixtures to replace R134a in automotive air conditioners. The hydrocarbons investigated are R290, R600 and R600a. The air conditioner, with a capacity of 3.5 kW driven by a diesel engine, is charged and tested with four different mass fractions of HC mixtures. The experiments are conducted at the same ambient conditions. The temperature and pressure of the refrigerant at every major position in the refrigerant loop, humidity of air and refrigerant mass flow rate, engine speed and torque are recorded and analyzed. The parameters used to investigate are the refrigeration capacity, the compressor power and the COP. The results show that 50%R290/40%R600/10%R600a is the better substitute for R134a among the considered HC mixtures.

5. EXPERIMENTAL SETUP

Figure 5.1 shows a photographic view of the domestic refrigerator of Kelvinator made with 169 liter capacity with testing facility. The cabinet was made of pressed steel with smooth and water proof outside shell. Expanded polystyrene panels were installed between the outer and the inner shells to minimize heat gain. Filter-drier is installed before the capillary tube to absorb the moisture which may exist in the refrigerant circuit. As the refrigerant is condensed in the condenser, it flows through the high-side filter drier into a capillary tube. The test rig used for the experiment is a domestic refrigerator designed to work with R134a. It consists of an evaporator, wire mesh air cooled condenser and hermitically sealed reciprocating compressor. Four pressure gauges were installed at compressor inlet and outlet, condenser outlet and evaporator inlet. All these pressure gauges were fitted on a wooden panel to avoid vibration during testing. The all the ten points of the thermo couple wire were connected to the thermocouple scanner. Thermocouple scanner is a device to read the measured temperatures. Ten calibrated temperature sensors were installed at the evaporator inlet and outlet, compressor suction and discharge, condenser inlet, condenser outlet, freezer compartment and refrigerator cabin. In addition, the consumed voltage and current were recorded. The flow meter which was connected to the pipe between condenser and capillary tube was also fixed on the wooden panel. The data was collected through data storage device of Human Machine Interface (HMI) and records once in every 10seconds. To check the quality of condensed liquid flowing a sight glass is provided.

Figure 5.1 Photographic view of experimental setup

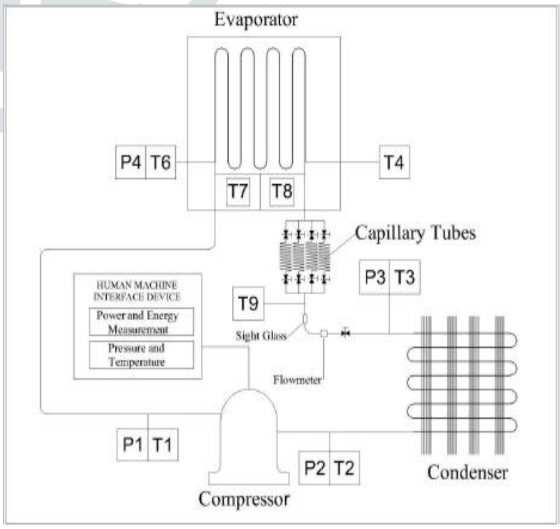


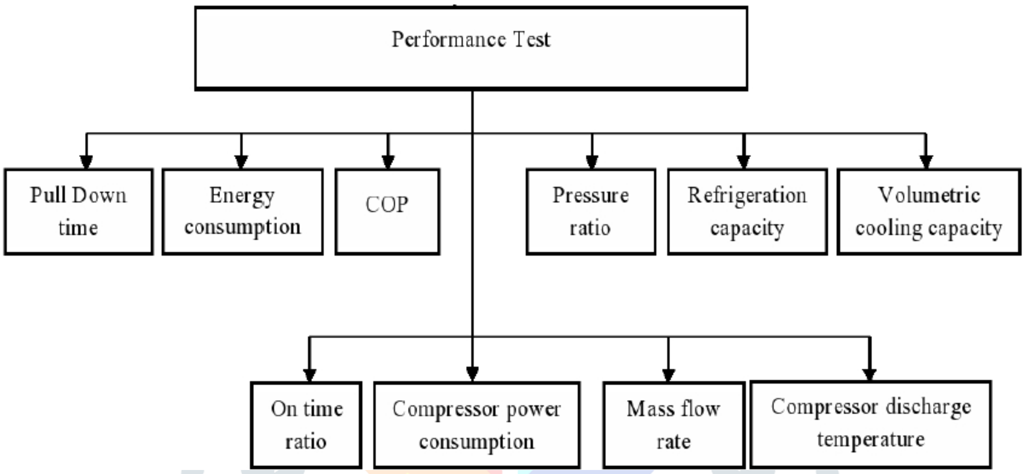
Figure 5.2 Schematic diagram of measurement system in experimental setup

Table 5.1 technical specifications of domestic refrigerator test unit/Measured quantities with their range and accuracy

Storage Volume	169L
Current rating	1.1 max
Voltage	220-240V
Frequency	50Hz
No. of. Doors	1
Refrigerant type	R134a
Defrost System	Auto defrost
Refrigerant charged	0.140 kg
Capillary tube length	3.35m
Capillary tube inner diameter	0.00078m
Cooling capacity	182 W

Quantity	Range	Accuracy
Temperature	-40°C to 110°C	+0.1°C
Power consumption	0 to 1000W	1W
Voltage	0 to 240V	0.1V
Current	0 to 10A	0.1A
Pressure	0 to 150MPa	+0.7kPa
Refrigerant flow meter	0 to 100	cc/s 0.1 cc/s

5.1 Performance Test



6. RESULT AND DISCUSSIONS

In this chapter the performance of the refrigerator for different charges of R440A and R429A were analyzed and discussed. The optimum charge masses for the alternative refrigerants were determined and compared with the performance of the base refrigerator working with R134a. The comparison was based on the pull down time, energy consumption, on time ratio, volumetric cooling capacity, refrigerating effect, compressor power, and coefficient of performance, discharge temperature, pressure ratio and total equivalent warming impact.

Also for the refrigerant mixture R429A, capillary tube length and charge mass was optimized for better performance. The results are presented and compared with the base refrigerator working with R134a. The results of the experimental investigations were also analyzed and compared with the predicted values by using Taguchi Technique.

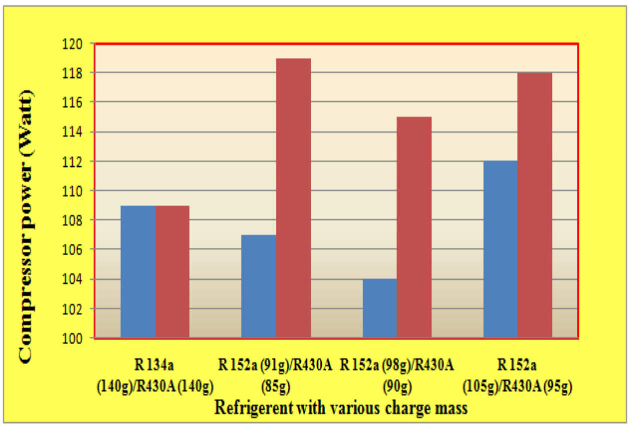


Figure 6.1 Variation of Compressor Power with various refrigerants at -at -16°C evaporator temperature

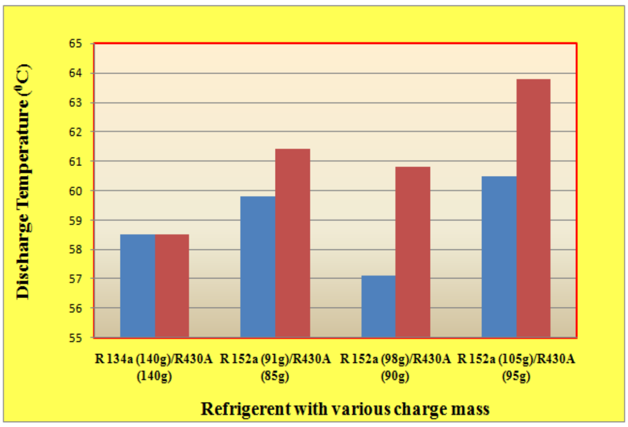


Figure 6.2 Variation of Discharge Temperature with various refrigerants 16°C evaporator temperature

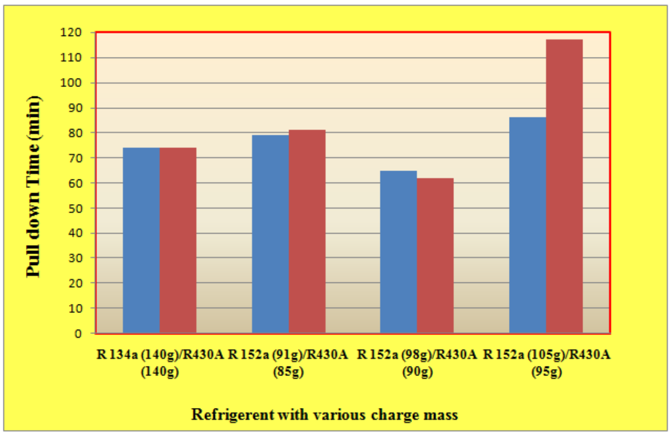


Figure 6.3 Variation of Pull down Time with various refrigerants at -16°C evaporator temperature

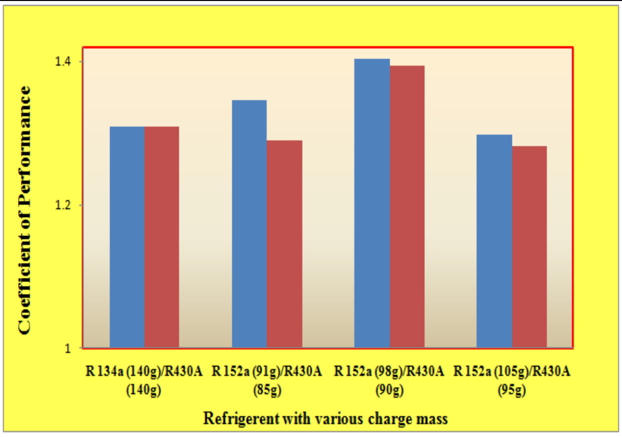


Figure 6.4 Variation of COP for R134a (140g) and various charge mass of R152a and R430A

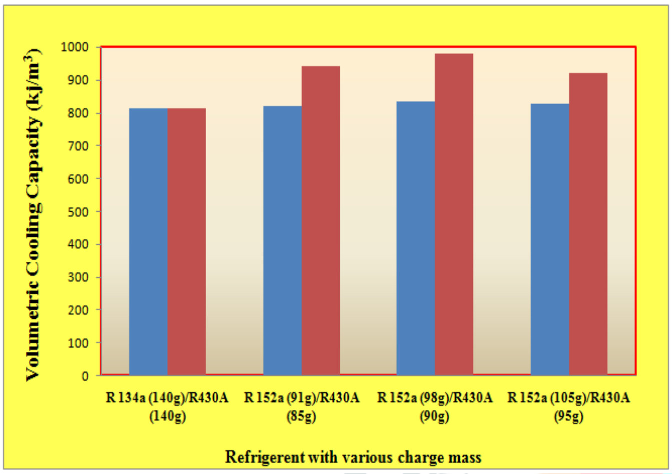


Figure 6.5 Variation of Volumetric Cooling Capacity for R134a (140g) and various Charge Mass of R152a and R430A

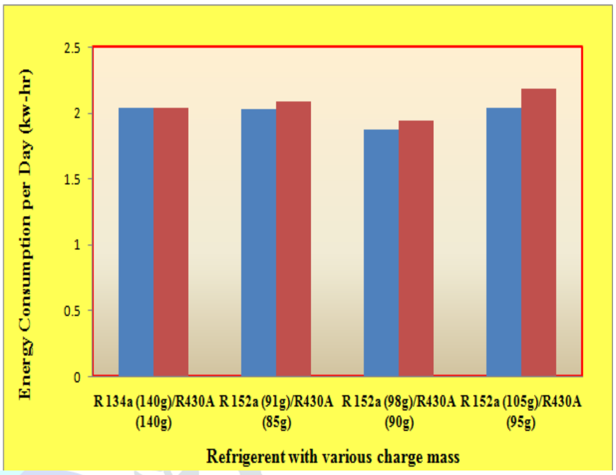


Figure 6.7 Variation of Energy Consumption per Day for Various charge mass of R152a and R430A

7. CONCLUSIONS

- The pull down time for R440A and R429A is 12.16% and 16.22% lower than that of R134a.
- The refrigeration capacity of R440A and R429A is higher than that of R134a by about 2.3% and 12.3% respectively. The latent heat of vaporization for R440A and R429A is higher than that of R134a.
- The COP of R440A and R429A is higher than that of R134a by about 7.15% and 6.49% respectively.
- The energy consumption of the compressor for R440A and R429A is 8.18% and 4.83% respectively lower than the R134a.
- The compressor discharge temperature of the domestic refrigerator operating with R440A and R429A is 2.34% lower and 3.93% higher respectively than the R134a

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