PERFORMANCE ANALYSIS OF HYBIRD ALTERNATIVE REFRIGERANT TO REPLACE R134a IN DOMESTIC REFRIGERATOR

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Abstract- Experimental investigation were carried out with an alternative eco-friendly refrigerant with better co efficient of performance (COP), reduced Ozone Depletion potential (ODP), and Global Warming Potential (GWP). This investigation has been accessed using a hydrocarbon refrigerant mixture composing of R152a/R290/R600a in the ratio of 70:25:5 by weight and by another refrigerant R134a. The performance characteristics of the domestic refrigerator were predicted using continuous running tests under different ambient temperatures. The obtained results showed that the hydrocarbon mixture has lower values of energy consumption, pull down time and ON time ratio also have higher co-efficient of performance (COP). Thus the performance of the alternate refrigerant derives the better choice than R134a.

Keywords: *Domestic refrigerator, Alternative refrigerant, R152a, R134a, R290, R600a.*

1. INTRODUCTION

R134a is used nowadays as the working fluid in domestic refrigerators. But it was found that the R134a increasing significantly to the world's greenhouse warming problem. This caused scientists to investigate more environmentally friendly refrigerants than HFC refrigerants for the protection of the environment such as hydrocarbon mixtures as working fluid in refrigeration and air conditioning systems [1]. Results from researchers show that the ozone layer is being depleted due to the presence of chlorine in the stratosphere. The general consensus for the cause of this that CFCs and HCFCs are large class of chlorine containing chemicals, which migrate to react with ozone. This leads to the strict prohibition of CFCs. The R134a was the first chlorine-free refrigerant discovered [2]. Recently, The Ozone Potential (ODP) and Global Warming Potential (GWP) have become the most important criteria in the development of new refrigerants apart from the refrigerant CFCs and HCFCs, both of which have high ODP and GWP due to their contribution to ozone layer depletion and global warming [3].The possibility of using hydrocarbon mixtures as working fluid to replace R152a in domestic refrigerators has been evaluated through the simulation analysis. This simulation, Concludes that the hydrocarbon refrigerants offer desirable environmental requirements. The performance of R152a in the domestic refrigerator was constantly better than those of R134a and R290a throughout all the operating conditions, which shows that R152a can be used as replacement for R134a in domestic refrigerator [4].

The hydrocarbon mixture (R290 and R600a) in the ratio 45.2:54.8 by weight is investigated in the domestic refrigerator in which the COP is improved up to 3.6% and also reduce the indirect global warming due to its higher energy efficiency [5]. The propane/iso-butane mixture at 0.6 mass fraction used as the refrigerant has a 3-4% higher energy efficiency and faster cooling rate [6]. The energy analysis using Taguchi method indicates that the charge amount required was 50g which brings economic advantages and also reduces the risk of flammability of the hydrocarbon refrigerant. The amount of total energy destruction in optimum condition is 45.05% of the base refrigerator [7]. Researches on R290 and R290/R600a for substituting R134a in a large capacity chest freezer were done.

This work concluded that the data of power consumption of R290 is lower by 26.7% and its charging amount is lesser than that of R134a.The COP of R290 is lower by about 4.7% than that of R600a, so that the working fluid R290/R600a in an appropriate proportion can improve the energy conversion effect. Further, this hydrocarbon mixture has an elevated effect on energy conservation when a specialized compressor is designed [8].In the present work, the problem of R134a is identified from environmental site and the alternative refrigerants R152a are selected. Then, their mass flow ratio are mixed and a better refrigerant is chosen with better mixing ratio. Thereby, the COP of the alternate refrigerant R152a/R290/R600a and R134a are compared. Hence, the main objective is to select an alternate refrigerant with an increased Coefficient of Performance (COP) and to reduce Global Warming Potential (GWP) and Ozone Depletion Potential (ODP) hydrocarbon mixture R152a/R290/R600a in the ratio of 70:25:5 by weight.

2. EXPERIMENTAL METHODOLOGY

The first step is to study the alternative refrigerant to replace R134a in a domestic refrigerator.

The details of the experimental setup is shown in Table 1.

Table.1 Details of Experimental Setup

Description	**Dimension/Range**
Refrigerator Capacity	125 litres
Refrigerator company name	LG
Capillary Tube	0.031mm
Compound Gauge	-30-220psi
Pressure gauge	0-300 psi
Vacuum Pump	-30PSIG
R32/R600a/R290	100gm

The R134a domestic refrigerator setup consist of a hermetically sealed compressor, natural convection air cooled condenser having a cooling capacity level of 5.67KW/hr. an evaporator and copper capillary tube whose schematic diagram and photographic view of the experimental set up is given in the fig 1 and fig 2. Pressure gauge is attached at the compressor inlet and outlet. Compound gauge is fitted at the condenser outlet. Evacuation of moisture takes place with the help of service port. Vacuum pump is used for evacuation and through the charging system refrigerant was filled in the refrigeration system. Properties of R152a/R290/R600a refrigerant from ASHRAE handbook are given to find the properties of the different refrigeration system.

Table.2 Properties of R152a, R290, R600a

Data	Refrigerants			
	R134a	R152a	R600a	R290
Natural	No	No	Yes	Yes
ODP	0	0	0	0
GWP (100 yrs)	1300	0	0	0
□ (kg/m^3)	1206.35	2700	550.65	492.65
Flammability limits (%)	None	3.80	1.9-10.0	2.1-11.4
molecular mass(kg/mole)	102.03	66.05	58.1	44.1

Table 2, shows the properties of various refrigerants from ASHRAE hand

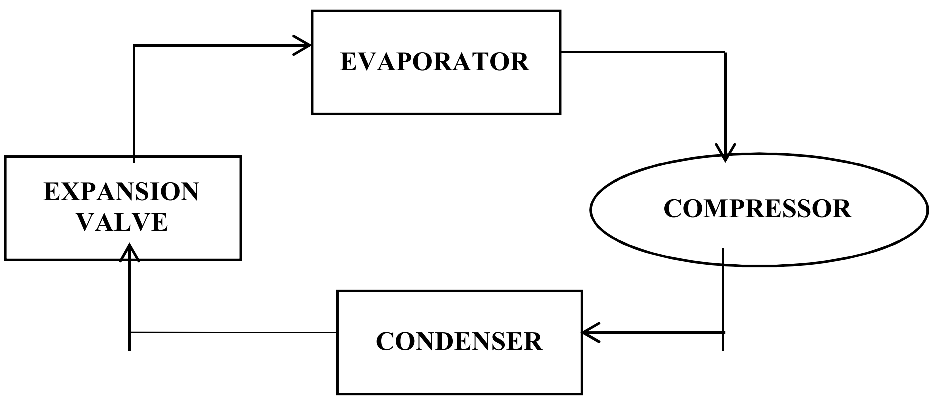

Figure 1 Schematic diagram of the Experimental setup

Experimental setup

Figure 2 Photographic View of the Experimental setup

3. EXPERIMENTAL PROCEDURE

Initially, R-134a is used as a working fluid at room temperature of 32^{0}C. Pressure and temperature in the inlet and outlet of the compressor, condenser pressure and temperature, evaporator outlet temperature are monitored in every one hour. The Compound pressure gauge and temperature sensors are mounted on the both ends of the compressor and condenser to measure the pressure and temperature of the refrigerant respectively. Finally COP and Mass flow rate is evaluated for the working fluid R134a. Then working fluid is released to the ambient and it can be fully evacuated by using vacuum pump running for three hours. Then R152a/R290/R600a are mixed in the proportions of 70:25:5: used as refrigerant in the refrigerator. The Same procedures are repeated to calculate the COP and Mass flow rate for those mixtures of gases.

4. RESULTS AND DISCUSSION

The assumptions used in the R134a domestic refrigerator are

- No sub cooling and super heating takes place.

- No heat losses and no heat gain from or to the system.
- No pressure drop through the pipe line in the refrigerator.
- Steady state condition.

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Experimental results for COP and Mass flow rate are determined using REFPROP software. The various equations used for calculating the parameters under the study are given below Coefficient of Performance (COP), Mass flow rate, cooling capacity is calculated using some given values.COP is ratio between refrigeration effect and work done.

$$\textbf{Refrigeration effect} = h_1 - h_4,$$

where, **h_1**- compressor side enthalpy.

h_4- expansion enthalpy.

$$\textbf{Work done} = (h_2 - h_1)$$

where, **h_2** – compressor enthalpy.

$$\textbf{COP} = (h_1 - h_4) / (h_2 - h_1)$$

Mass flow rate is ratio between cooling capacity and refrigeration effect.

$$\textbf{Capacity = mass flow rate} *(h_{fg}).$$

where , **Capacity** =5.67kW

h_{fg} – is vapour enthalpy.

Super-heated vapour refrigerant at compressor enthalpy exit (h_2) .

$$h2 = h1 + (h2 - h1) / (\eta)$$

where, $h_{2\ is}$ the superheated vapour enthalpy at compressor exit.

COMPARISION OF REFRIGERANT R134A AND ALTERNATE REFRIGERANT MIXTURE (R152a/R290/R600a) IN HALF LOADING CONDITION

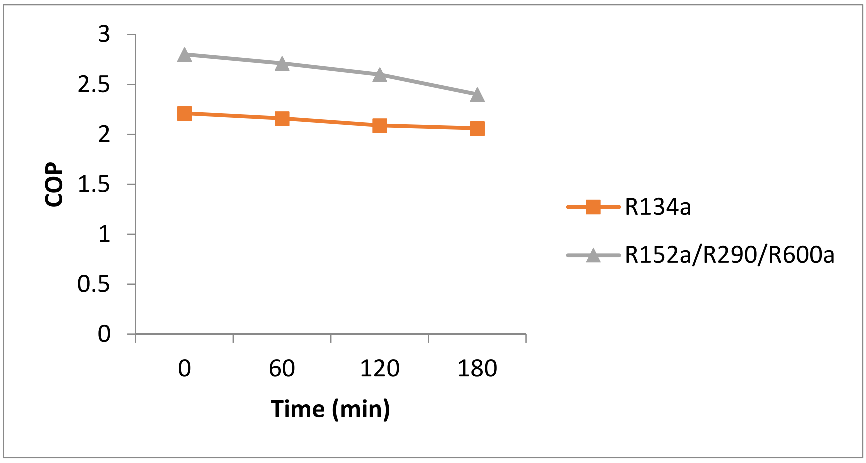

Figure.3 Variation of COP with respect to time for refrigerant R134a and alternate refrigerant mixture (R152a/R290/R600a).

Figure 3 shows that the variation of Cop with time in half loading ON condition the pressure and temperature at the suction and discharge of the compressor and that of condenser are measured under half loading condition by switching the refrigerator ON. COP decreases with increases in time. Due to suction pressure and temperature decreases in the compressor i.e., work done in the compressor decrease.R152a/R290/R600 refrigerant mixture has high COP compared with R134a.

COMPARISION OF REFRIGERANT R134A AND ALTERNATE REFRIGERANT MIXTURE (R152a/R290/R600a) IN FULL LOADING CONDITION

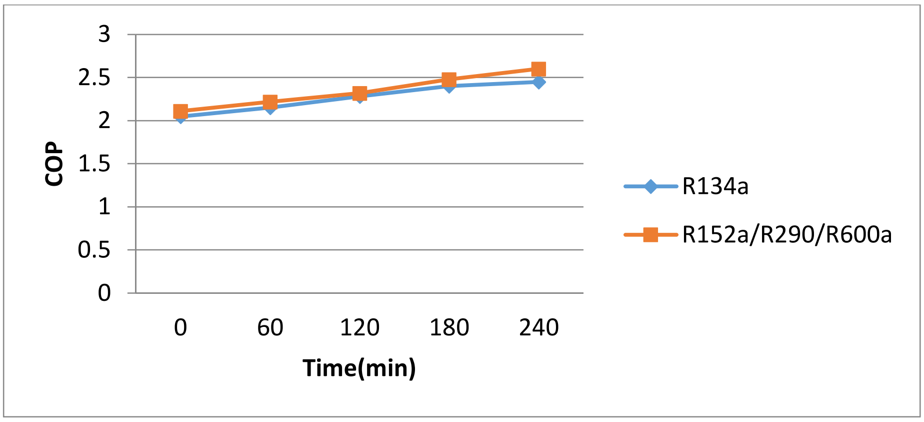

Figure.4 Variation of COP with respect to time

Figure 4 shows that the Variation of COP with time in Full loading condition. The pressure and temperature at the suction and discharge of the compressor and that of condenser are measured under loading condition by switching the refrigerator ON. The COP increases in time. Due to the suction pressure and temperature increases in compressor i.e,work done in the compressor increases. Compared R134a the COP of (R152a/R290/R600a) mixture is higher that of R134a in full loading condition

COMPARISION OF REFRIGERANT R134A AND ALTERNATE REFRIGERANT MIXTURE (R152a/R290/R600a) MASS FLOW RATE

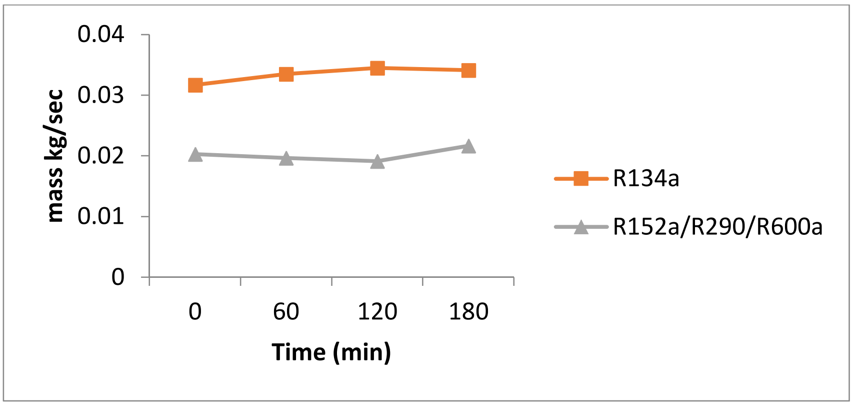

Figure.5 Variation of mass flow rate with respect to time

Figure 5 shows the mass flow rate of the R134a refrigerant and mixture (R152a/R290/R600a) measured at different time intervals by switching the refrigerator ON. Mass flow rate decreases with increases in time, after that it remains constant. Initially Refrigerant takes more time to flow through the compressor.

VARIATION OF CABIN AIR TEMPERATURE WITH RESPECT TO TIME

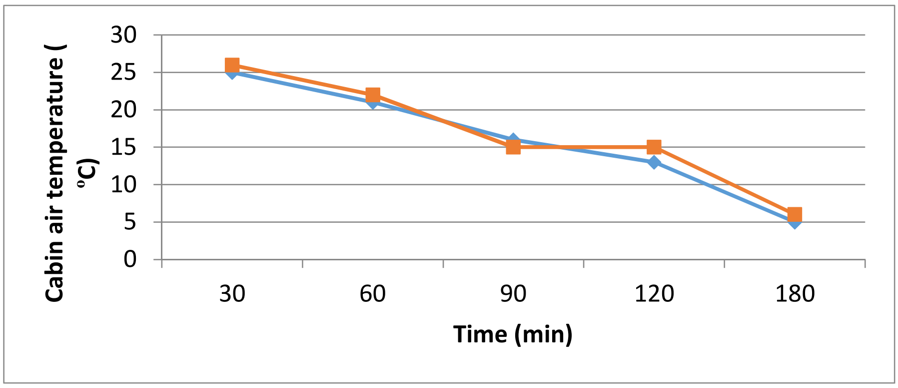

Figure.6 variation of cabin air temperature with respect to time

Fig.6 shows that the increase in running time of refrigeration system will decrease the cabin air temperature continuously when compare to R134a the alternate refrigerant R152a/R290/R600a gives high cooling effect. A cabin temperature reducing in pull down time in the refrigerator was observed.

COMPARISON OF R134a AND R152a/R290/R600a

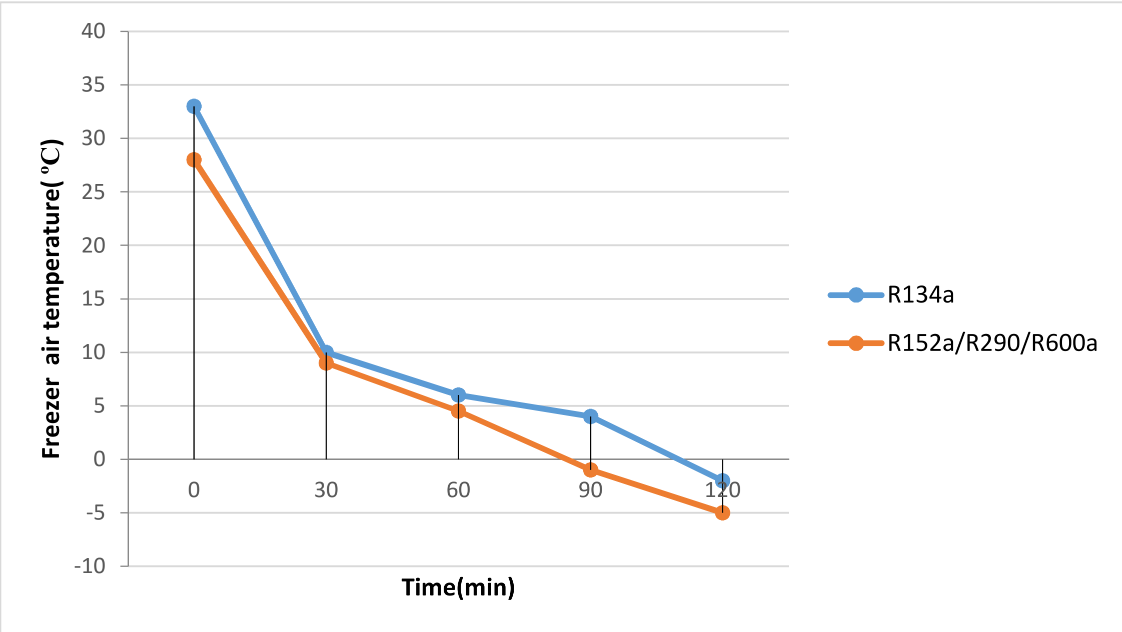

Figure.7 Variation of freezer air temperature vs time at 33ºC ambient temperature

Figure 7 shows the Running time is required to reduce the air temperature inside the refrigerator from ambient condition to the desired freezer and cabin air temperature of -5 and 10ºC in the freezer and cabin, respectively. Pull down time were carried out at 33ºC ambient temperature. The pull down time 108min was required reach the desired freezer air temperature (-12ºC) for R134a base line test as indicated figure 6 an increase in running time by about 2.5% was observed for mixture due to insufficient refrigerants quantity. The pull down was reduced for alternate refrigerant respectively compare to R134a due to high heat of vaporization.

5. CONCLUSION

The problem of R134a refrigerant is identified from the environmental site. An alternative refrigerant is chosen with better COP and is compared with R134a. The mass flow rate and COP of the chosen refrigerant is calculated and is compared with R134a. Mass concentration ratio is (70/25/5) mixer time that COP and Mass flow rate calculated. Condensation temperature is fixed (32ºC) and evaporator temperature is also fixed (-5ºC) that time calculated COP and Mass flow rate. R134a at unloading ON condition time, the COP and mass flow rate were lower than (R152a/R290/R600a). Using (R152a/R290/R600a) at loading ON condition time, the COP and mass flow rate values are higher than R134a. The (R152a/R290/R600a) is starting cooling process lower than R134a. Mixing refrigerants GWP (global warming potential) is lower than R134a. Mixing refrigerants GWP (global warming potential) is lower than R134a. Freezer air temperature decreases with in less time by using alternate refrigerant R152a/R290/R600a when compare to R134a

NOMENCLATURE

c	Specific Heat (kJ/kg K)
C	Clearance Ratio
COP	Coefficient of Performance
M	Mass Flow Rate (kJ/kg)
n	Specific Enthalpy (kg/S)
N	Compressor Speed (Rpm)
P	power (kw)
P	Heat Transfer Rate (kw)
T	Temperature (^{O}c)
T_{cond}	Condenser Temperature (^{O}c)

P_{cond} Condenser Pressure (Bar)

R134a 1,1,1,1 Tetraflouroethane

R152a Difluroethane

R600a Isobutene

R290 Propane

ODP Ozone Depletion Potential

GWP Global Warming Potential

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