

# EXPERIMENTAL INVESTIGATION OF A REFRIGERATOR BY USING ALTERNATIVE ECO FRIENDLY REFRIGERANTS (R600A & HC MIXTURE)

<sup>1</sup>NULAKA RAJESWARI, <sup>2</sup>Dr. B.OMPRAKASH, <sup>3</sup>Dr. R.GANAPATHI,

<sup>1</sup>M.Tech, Mechanical Engineering, JNTUA College of Engineering Ananthapuramu, A.P, India

<sup>2</sup>Asst.Professor, Mechanical Engineering, JNTUA College of Engineering Ananthapuramu, A.P, India

<sup>3</sup>Professor, Mechanical Engineering, Anurag Engineering College Kodada, TS, India

**ABSTRACT:** *In the present days refrigeration became a common human need but due to the release of green house gases from the refrigerators in to the earth's atmosphere, causes high global warming and in turn destructing the ozone layer of atmosphere. In concern of the earth's environment, Montreal and Kyoto protocols proposed for alternative eco-friendly refrigerants. In the current work, experimental investigation on VCRS system tested with R600a and hydrocarbon mixture (R290/R600a) as refrigerants as they have zero ODP and very low GWP related to the refrigerant R134a. Due to the higher value of latent heat of hydrocarbons, the amount of refrigerant charge will be relatively lower than R134a. By using R600a and hydrocarbon mixture refrigerants of charges 50g, 55g and 60 g are tested individually for performance characteristics and critical correlations are drawn between the refrigerants and represented by graphical representation. Refrigeration effect of R290/R600a (50/50 by wt %) mixture was 21.4% higher than R600a for 55g charge. The obtained results proved that the overall performance of 55g (R290/R600a) mixture could be considered as the best eco-friendly alternative refrigerant phase out R134a refrigerant.*

**Keywords:** *Eco-friendly refrigerants-R600a(isobutane), Hydrocarbon mixture (R290/R00a), 50g, 55g,60g, of refrigerant charge, performance.*

## I. INTRODUCTION

In late 1800s and in early 1900s, the most used refrigerants were natural refrigerants such as carbon dioxide, ammonia, Sulphurdioxide, and methyl chloride. But due to their toxic or hazardous nature, a safer class of alternative refrigerants came on stage with the invention of CFCs and HCFCs. In 1930s, CFCs and HCFCs have been accustomed in domestic refrigerators as refrigerants due to their suitable properties such as stability, non-flammability, non-toxicity, eminent thermodynamic properties, which led to their common wide spread use by both consumers and industries across the globe, exclusively as refrigerants in refrigeration and air-conditioning systems. However, many researchers found that Ozone layer is being depleted due to the presence of chlorine in the stratosphere. The general agreement for this cause is that CFCs and HCFCs are sound class of chlorine containing refrigerants, which disperse to the stratosphere where ozone reacts with them. Later, Chlorine atoms continue to convert more ozone to oxygen. There by depleting the ozone layer of earth, which shields the earth's atmospheric surface from UV radiations? This ozone layer depletion threatens earth's environment that the CFCs and HCFCs have significantly contributed to the global warming problem, as its global warming Potential (GWP) of CFCs is 8500 for over 100 years. This resulted in a series of international treaties such as MONTREAL protocol to phase out of CFCs and HCFCs by 1996 and KYOTO protocol, even new developed HFC refrigerants like R-134a should be gradually phased out on or before 2030, due to their high GWP and the concentration of green house gases in the atmosphere. Subsequently it was decided to decrease global warming by subjection of green house gases emissivity. Hence to counter balance the global ecological goals, conventional refrigerants should be replaced by environmentally suitable alternative refrigerants for HFCs such as hydrocarbon (HC) R600a and mixtures of HCs R290/R600a. these natural refrigerants are considerably cheaper than their significant alternatives.

## II. SELECTION OF REFRIGERANT

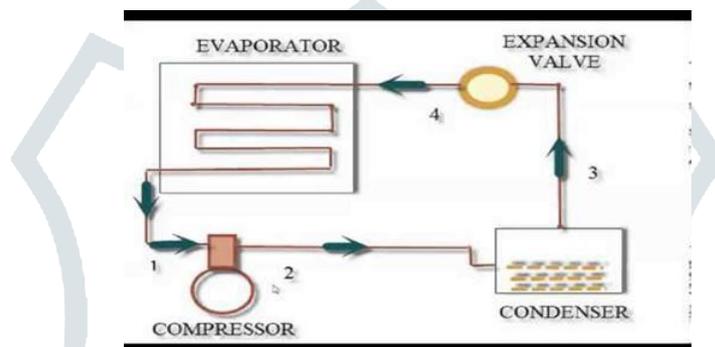
To substitute fully halogenated CFC refrigerants, Hydrocarbons (HCs) and Hydro Fluoro Carbons (HFCs) provide a best alternatives as they contain no chlorine atom at all, therefore have zero ODP. Even, hydro-chlorofluorocarbons (HCFCs) like R22 and R123 which do have chlorine atom, but in association with Hydrogen (H)-atoms, have much reduced ODP. The association of one or more Hydrogen -atom allows them to dissociate faster in the lower atmosphere of the earth surface. Thus, released Chlorine gets absorbed by rain water like the chlorine used in the chlorination of water. So fewer chlorine atoms reach the ozone layer in the upper atmosphere. However, HCFCs have a certain level of ODP in addition to GWP. Hence, these also have to be phased out ultimately. The HFCs on the other hand, because of their H-content may be flammable to some extent. If the molecule is rich in H -atoms, then the degree of flammability is high. Pure HCs are highly flammable due to the presence of H-atoms. We know that Normal Boiling Point (N.B.P.) is the single most important characteristic of a substance to be used as a refrigerant. It also governs the equipment, type of application and the refrigerating capacity for which a particular refrigerant is to be used. From this point of view, substances with their N.B.P.s in the range of  $-50^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$  are considered suitable for use as refrigerants. On the basis of N.B.P.s it has been observed HFC s R134a are potential alternatives to R12, HCs mixture R600a /R290 can also be used in place of R12. Isobutene R600 a is the most used hydrocarbon refrigerant in domestic refrigerators. In 21<sup>st</sup> century, the use of isobutene and its mixtures was about 34% in domestic refrigerators and freezer at global level. Thus, HCs like R600 a and its mixture like R290/R600 a are widely uses in air conditioners, heat pumps, and commercial refrigeration systems.

**Table 1 Properties of possible refrigerant substitutes**

Refrigerant	Formula	Molecular weight(Kg/KMol)	lower flammability limit	safety group	ODP	GWP (100 yr)
R134 a	CH <sub>2</sub> FCF <sub>3</sub>	102.0	Non flammability	A <sub>1</sub>	0	1300
R600a	C <sub>4</sub> H <sub>10</sub> / isobutene	58.1	1.8	A <sub>3</sub>	0	<20
R290	C <sub>3</sub> H <sub>8</sub>	44.0	2.3	A <sub>3</sub>	0	<20
R436a	C <sub>3</sub> H <sub>8</sub> +C <sub>4</sub> H <sub>10</sub> / isobutene	49.3	3.7	A <sub>3</sub>	0	3

### III.EXPERIMENTAL SET UP

A Domestic Refrigerator of capacity 165 liters is selected. As shown in the Fig.1, it consists of hermitically sealed compressor to discharge the refrigerant at high pressure, air cooled condenser acts as heat exchanger in which both liquid and vapor phases of refrigerant takes place at constant pressure conditions, a capillary tube as expansion valve to expand the refrigerant, and evaporator with copper tubing in which the latent heat of refrigerant gets absorbed and cooling takes place. Temperature and pressure readings are taken from the digital thermocouples and pressure gauges which are arranged at the inlets and outlets of compressor, condenser and evaporators respectively. Energy meter was setup to take the energy consumption readings during the process of the cycle.



**Figure.1** schematic diagram of VCRS system

Before charging the refrigerant in to the compressor, we need to evacuate the cycle because any presence of air or non-condensable gases in the refrigerant may cause a reduction in cooling capacity of the system and a rise in power input due to high discharge pressure. In such cases, oxygen or air cause the formation of sludge and there by shortening the life of compressor. Therefore, the non-condensable gas in the cycle should not exceed 1% volume. The recommendable vacuum is 0.008 mmHg, and the evacuation time must be 45 minutes or more with the capacity of vacuum pump of 300L/min or more and it is better to vacuum simultaneously in low and high pressures sides for at least 45 minutes with a pump per system.

For achieving better performance and long life reliability in domestic refrigerator and freezer, purity of R 134 a, R600 a and hydrocarbon mixture R290/R600 a was equal to 99.5%, that the purity of refrigerants which are used in household refrigeration cycle should be more than 99.5% .

The following steps to be followed for the experimental analysis:

1. At first leakage tests are done by using soap solution in order to test the condenser and evaporator pressures and check purging daily for 10 hours and found that there are no leakages which was required absolutely for the present investigation to implement further experiment.
2. Charge the 105 g of R134a refrigerant with the help of charging unit and weight measuring device with +0.01gm accuracy.
3. Switch on the refrigerator and observed for 3 hour and then the pressure and temperature readings at each inlet and outlet sections of compressor, condenser and evaporator are taken.
4. The characteristic performance of the existing system is investigated, with the help of pressure gauge and temperature readings at certain intervals of temperature difference.
5. The actual refrigerating capacity and cop of the refrigerated system were calculated as per the procedure
6. The energy consumption of the compressor also measured by the energy meter readings.

Similarly other two refrigerants (R600a and HC Mixture (R290/R600a)) were tested with different weights of 50 g, 55g, and 60g charged as above process with the help of refrigerant charging unit. And next similar observations are noted down such as suction and discharge compressor pressures, temperatures at compressor inlet & outlet, condenser outlet and evaporator outlet. The measured values were used for study the characteristic performance of the system.

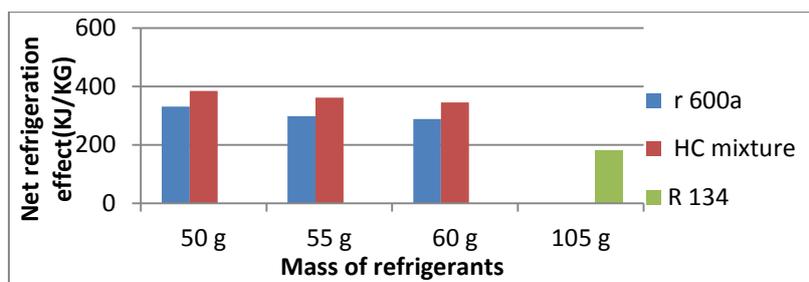
### IV.RESULT AND DISCUSSION

By adopting the above described test procedure, performance parameters and energy consumption with R134, R600 and HC mixture of defined weights were conducted. The experimental results obtained from the performance analysis of 50g, 55g and 60 g of R600 a and 50g,55g,and 60 g of HC mixture ( R290/R600 a) are discussed with reference to the parameters such as Net refrigeration effect, compressor work, energy consumption, COP.

#### 4.1. Net Refrigeration effect

Fig.2 shows the variations of net refrigerating effect with respect to weight of the refrigerants. It was noted that the HC mixture has the highest refrigerating effect than the other two refrigerants R134a and R600 a. It is also observed that low charge of the HC refrigerant gives

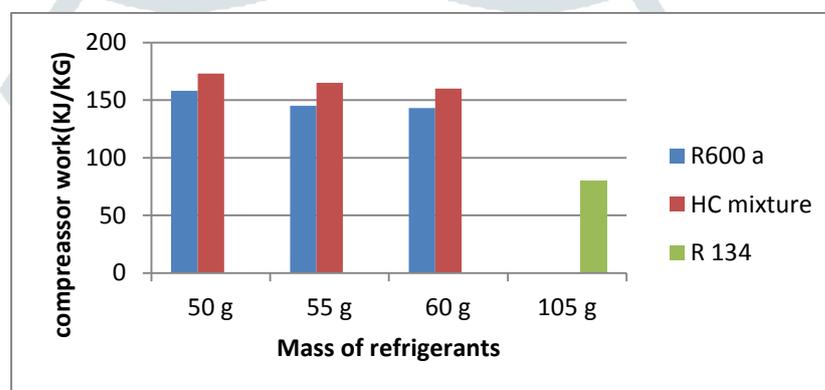
better result than the other two refrigerants. For  $-10^{\circ}\text{C}$  temperature, HC mixture gives 16.3%, 21.4% 19.3% and 52.98% higher RE than R600a(50g,55g,60g) and R134a respectively. From the above HC mixture has highest RE than the other refrigerants.



**Figure.2** Net refrigeration effect Vs mass of refrigerants R600a,HC mixture (R290/R600a – 50/50 by wt%) and R134a at  $-10^{\circ}\text{C}$  evaporator temperatures

**4.2. Compressor work**

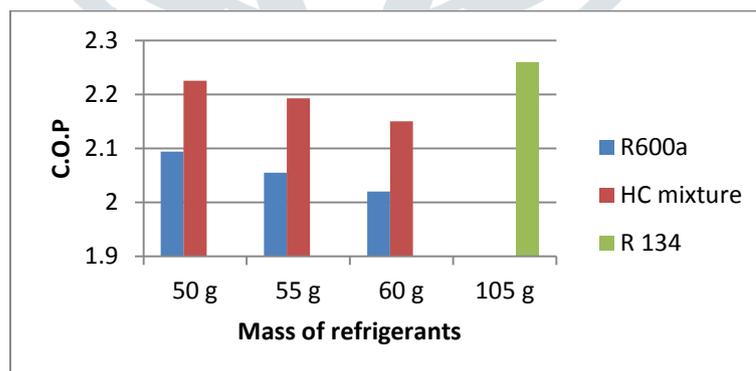
Fig.3 shows the variations of compressor work with respect to weight of the refrigerants. It was noted that the HC mixture has the highest compressor work than the other two refrigerants R134a and R600a. It is also observed that higher discharge pressure of HC mixture increases the work of the compressor than the other two refrigerants. For  $-10^{\circ}\text{C}$  temperature HC mixture gives 9.4% ,13.7%, 11.8% and 53.5% higher RE than R600a (50g,55g, and 60g ) and 105g of R134a respectively. From the above , 50 g HC mixture required lower work than the other weight of refrigerants.



**Figure.3** Compressor work Vs mass of refrigerants R600a,HC mixture (R290/R600a – 50/50 by wt%) and R134a at  $-10^{\circ}\text{C}$  evaporator temperatures

**4.3. Coefficient of performance**

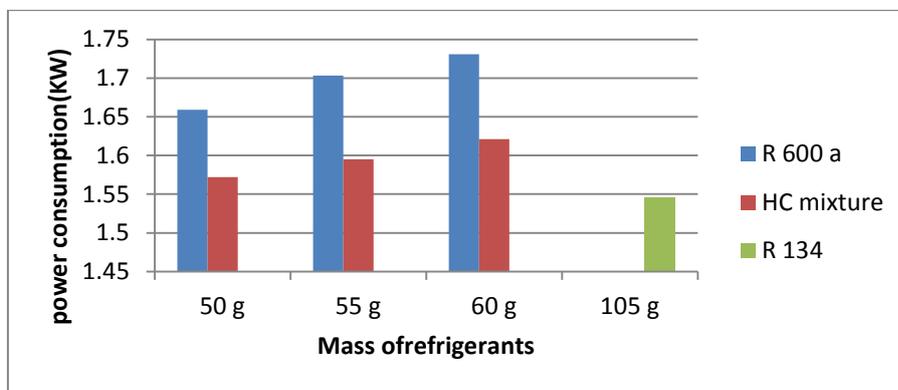
Fig.4 Shows the variations of coefficient of performance with respect to weight of the refrigerants. It was noted that the 50g of HC mixture has the highest coefficient of performance than R600a.it is also observed that higher RE of HC mixture increases the COP than the R600. For  $-10^{\circ}\text{C}$  temperature, 50g HC mixture gives 6.2% higher than R600a , but cop of R134 has highest cop due to its lower compressor work .



**Figure.4** COP Vs mass of refrigerants R600a, HC mixture (R290/R600a – 50/50 by wt%) and R134a at  $-10^{\circ}\text{C}$  evaporator temperatures

**4.4. Power consumption**

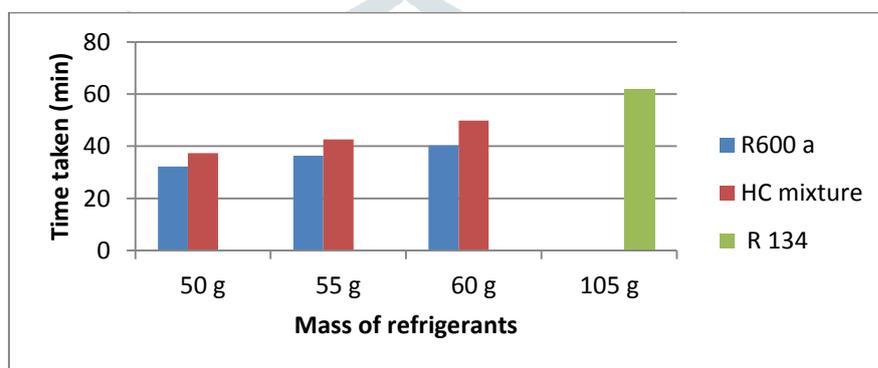
Fig.5 shows the variations of power consumption with respect to the weights of refrigerants. It was noted that the HC mixture has consumed less power than the R600a . 60 g of R600a refrigerant had consumed 1.731 KW of power . But R134a consumed least power than the HC mixture and R600a.



**Figure.5** Power consumption Vs Mass of refrigerants R600a,HC mixture (R290/R600a – 50/50 by wt%) and R134a at -10<sup>0</sup>c evaporator temperatures

**4.5. Time taken**

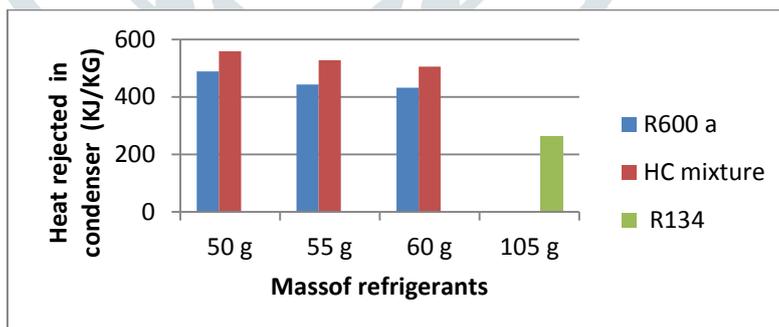
Fig.6 shows the variations of time taken with respect to the mass of refrigerants. It is clear that among all the refrigerant masses, 50 g of HC mixture has taken 32.2 minutes of time to deliver the performance of the system which was less amount of time. Whereas 50 g of R600a is the next opted refrigerant.



**Figure.6** Time taken Vs mass of refrigerants R600a,HC mixture (R290/R600a – 50/50 by wt%) and R134a at -10<sup>0</sup>c evaporator temperatures

**4.6. Heat rejected in condenser**

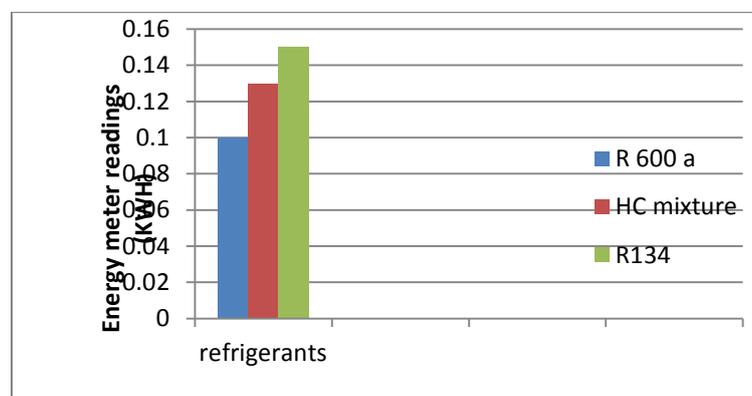
Fig.7 shows the variations of heat rejection in condenser with respect to the mass of refrigerants. It is clear that among all the refrigerants R134a has rejected less heat in the condenser i.e., 261 KJ/Kg. Greater the heat rejection in the condenser, higher the performance of the refrigeration system. It was observed that 50 g of HC mixture has the highest amount of heat rejection in the condenser than the all refrigerant masses.



**Figure.7** Heat rejected in condenser Vs Mass of refrigerants R600a, HC mixture (R290/R600a – 50/50 by wt%) and R134a at -10<sup>0</sup>c evaporator temperatures

**4.7. Energy meter readings**

Fig.8 shows the variations of energy meter readings with respect to the mass of refrigerants. It is clear that R134a refrigerant has the highest energy meter reading 0.15 KWH. The more energy meter reading, the greater the emission of gases in to the atmosphere. So, it is noted that R600a has the low energy emission to the atmosphere.



**Figure.8** Energy meter readings Vs refrigerants R600a,HC mixture (R290/R600a – 50/50 by wt%) and R134a at  $-10^{\circ}\text{C}$  evaporator temperatures

## V.CONCLUSION

From the above discussion

- Refrigeration effect of HC mixture has the 16.3% , 21.4% and 19.3% higher than the R600a for the masses 50g, 55g and 60g respectively. And HC mixture has 52.9% higher than 105 g of R134a refrigerant.
- Compressor work of HC mixture has 9.4%, 13.7% and 11.8% higher than the R600a for the masses 50g, 55g and 60g respectively. And HC mixture has 53.7% higher than 105 g of R134a refrigerant.
- COP of HC mixture has 6.25%, 6.7% and 6.4% higher than the R600a for the masses 50g, 55g and 60g respectively. And HC mixture has 1.54% lower than 105 g of R134a refrigerant.
- Power consumed by HC mixture has 5.5%, 6.77% and 6.78% lower than the R600a for the masses 50g, 55g and 60g respectively. And HC mixture has 1.6% higher than 105 g of R134a refrigerant.
- Heat rejection in condenser of HC mixture has 14.1%, 18.9% and 16.8% higher than the R600a for the masses 50g, 55g and 60g respectively. And HC mixture has 53.2% higher than 105 g of R134a refrigerant.
- Energy meter readings of HC mixture has 30%, higher than the R600a . And HC mixture has 13.3% lower than 105 g of R134a refrigerant.
- Time taken by HC mixture has 16.1%, 17% and 22.3% higher than the R600a for the masses 50g, 55g and 60g respectively. And HC mixture has 39.6% lower than 105 g of R134a refrigerant.
- From all the above results , it was concluded that , all the performance parameter values for R134a, R600a, and HC mixtures bear similar. It is recommended that 55g of HC mixture may be adopt as the best alternative refrigerant to the R134a refrigerant. And 60 g of R600 a might be the next appropriate alternative refrigerant to R134a refrigerant applications.

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