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Exploring Eco-Friendly Alternatives: Experimental Study of a Refrigerator with R600a and HC Mixture Refrigerants

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Abstract: *The emission of greenhouse gases into the atmosphere by refrigerators is a major contributor to global warming and the subsequent destruction of the ozone layer, despite the fact that refrigeration has become an essential human need in recent decades. Montreal and Kyoto agreements advocated environmentally preferable refrigerants because of concern for the planet. Since R600a and a hydrocarbon combination (R290/R600a) have negligible ODP and very low GWP compared to the refrigerant R134a, they were used in the current work's experimental investigation of the VCRS system. Hydrocarbons have a larger latent heat value than R134a, hence a smaller refrigerant charge is required. Critical correlations are formed between the refrigerants, and they are graphically illustrated, utilizing R600a and hydrocarbon mixture refrigerants of charges 50g, 55g, and 60g. For a 55g charge, the cooling effect of a mixture of R290 and R600a (50/50 by weight percent) was 21.4% more than that of R600a alone. Based on the data, it was determined that a blend of 55 grams (R290/R600a) is the most effective environmentally friendly replacement for R134a refrigerant.*
Keywords: *Eco-friendly refrigerants-R600a (isobutene), Hydrocarbon mixture (R290/R00a), 50g,55g,60g,of refrigerant charge, performance.*

1. INTRODUCTION

Natural refrigerants such as carbon dioxide, ammonia, sulphur dioxide, and methyl chloride were widely employed in the late 1800s and early 1900s. However, due to their toxicity or danger, these refrigerants were eventually replaced by CFCs and HCFCs, a newer and safer class of refrigerants. CFCs and HCFCs have been commonly used by both consumers and industries across the globe, exclusively as refrigerants in refrigeration and air-conditioning systems since the 1930s. Their stable, non-flammable, non-toxic, and eminent thermodynamic properties made them ideal for use in home refrigerators. However, numerous scientists have discovered that chlorine in the stratosphere is depleting the ozone layer. There is widespread consensus that CFCs and HCFCs, a kind of chlorine-containing refrigerants, contribute to ozone depletion because they are released into the stratosphere and react with the gas there. Later on, more ozone is broken down into oxygen by chlorine atoms. As a result, we are losing the ozone layer that protects the Earth's surface from harmful ultraviolet rays in the atmosphere. CFCs and HCFCs have contributed significantly to the global warming problem; the GWP of CFCs is 8500 for over 100 years. This has prompted a number of international treaties, including the MONTREAL protocol, which called for the elimination of these substances by 1996, and the KYOTO protocol, which stipulated that newly developed HFC refrigerants like R-134a be phased out by 2030 at the latest. The resulting consensus was to curb the emission of greenhouse gases as a means of mitigating the effects of global warming. Hydrocarbon (HC) R600a and mixtures of HCs R290/R600a are two environmentally preferable alternatives to hydrofluorocarbon (HFC) refrigerants that can be used to achieve a better global ecological balance at a lower cost than conventional refrigerants.

2. SELECTION OF REFRIGERANT

Hydrofluorocarbons (HFCs) and hydrocarbons (HCs) are excellent replacements for completely halogenated CFC refrigerants since they contain no chlorine atom and, thus, zero ODP. Although HCFCs like R22 and R123 include chlorine atoms, they do so in combination with Hydrogen (H) atoms, resulting in significantly lower ODP. When two or more hydrogen atoms join forces, they can dissolve more rapidly near the Earth's surface. Chlorine that has been discharged into the atmosphere is absorbed by rainwater in the same way that chlorine used to chlorinate water is. Therefore, fewer chlorine atoms are able to penetrate the ozone layer far above the Earth. Nonetheless, HCFCs also have an ODP in addition to their GWP. Therefore, these will also need to be eliminated in the long run. In contrast, the HFCs may be somewhat combustible due to the hydrogen (H) they contain. The flammability of a molecule increases if it has a lot of hydrogen atoms. Due to the presence of H atoms, pure HCs are extremely combustible. As far as potential refrigerants go, the property with the most weight is Normal Boiling Point (N.B.P). It also regulates the appliances, applications, and cooling capacities that can safely employ a given refrigerant. In this view, potential refrigerants include compounds having N.B.P.s between 500 degrees Celsius (-460 degrees Fahrenheit) and 500 degrees Celsius (+46 degrees Fahrenheit). According to the N.B.P.s, the HFCs R134a and the HCs mixture R600a/R290 are both viable replacements for R12. The most common hydrocarbon refrigerant found in homes is isobutene R600 a. Isobutene and its derivatives were used in around 34% of all home refrigerators and freezers in the world in the 21st century. Commercial refrigeration systems, heat pumps, and air conditioning units all make use of hydrocarbons like R600a and its mixtures like R290/R600a.

TABLE1. Propertied of possible refrigerant sub statutes

Refrigerant	**Formula**	**Molecular weight(Kg/KMol)**	**Lower flammability limit**	**Safety group**	**ODP**	**GWP (100 yr)**
R134 a	CH_2FCF_3	102.0	Non flammability	A_1	0	1300
R600a	C_4H_{10}/ isobutene	58.1	1.8	A_3	0	<20
R290	C_3H_8	44.0	2.3	A_3	0	<20
R436a	$C_3H_8+C_4H_{10}$/ isobutene	49.3	3.7	A_3	0	3

3. EXPERIMENTAL SETUP

The 165-liter capacity of a home refrigerator is decided upon. An air-cooled condenser serves as a heat exchanger for the liquid and vapor phases of the refrigerant to occur at constant pressure conditions, an expansion valve in the form of a capillary tube allows the refrigerant to be expanded, and a copper-tubed evaporator absorbs the refrigerant's latent heat to produce cooling. The inlets and outlets of the compressor, condenser, and evaporator are equipped with digital thermocouples and pressure gauges, which are used to take temperature and pressure data. An energy meter was installed to record the amount of energy used throughout the cycle.

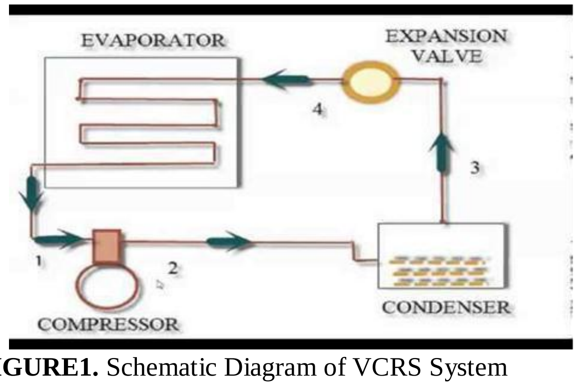

FIGURE1. Schematic Diagram of VCRS System

Since the presence of air or non-condensable gases in the refrigerant can reduce the cooling capacity of the system and increase the power input due to high discharge pressure, the cycle must be evacuated before the refrigerant is charged into the compressor. Compressors have shorter lifespans when exposed to oxygen or air, which leads to the development of sludge. As a result, the volume of non-condensable gas in the cycle must be kept below 1%. A vacuum of 0.008 mm Hg is recommended, and systems should be evacuated for at least 45 minutes using vacuum pumps with flow rates of at least 300 liters per minute (L/min). High and low pressure sides should ideally be evacuated at the same time.The purity of refrigerants used in the household refrigeration cycle should be greater than 99.5% in order to achieve higher performance and long life reliability in refrigerators and freezers. This holds true for R 134 a, R600 a, and the hydrocarbon mixture R290/R600 a.ThefollowingstepsTobefollowedfortheexperimentalanalysis:First, the condenser and evaporator pressures and purging are tested using soap solution for 10 hours per day, and it is found that there are no leakages, as was required in order to proceed with the current inquiry.Using the charging equipment and the weight measurement instrument, charge the 105 g of R134a refrigerant to an accuracy of +0.01 g.The fridge is turned on and monitored for three hours before pressure and temperature readings are recorded at the refrigerator's inlet and output locations.Using pressure gauge and temperature measurements at various temperature difference intervals, the defining performance of the current system is probed.Following the protocol, the true cooling capacity and coefficient of performance of the cooling system were determined.The information from the energy meter can also be used to calculate the compressor's energy usage.Using the same procedure and refrigerant charging device, we evaluated R600a and HC Mixture (R290/R600a) at 50 g, 55 g, and 60 g charge weights. In a similar fashion, the intake and outlet temperatures of the compressor, condenser, and evaporator are recorded, as well as the suction and discharge pressures of the compressor. The obtained data was analyzed to learn more about the system's typical behavior.

4. RESULT AND DISCUSSION

Performance metrics and energy consumption were evaluated using a predetermined mixture of R134, R600, and HC, as mentioned above. The parameters Net refrigeration effect, compressor work, energy consumption, and COP are examined in relation to the experimental data derived from the performance study of 50g, 55g, and 60g of R600 a and 50g, 55g, and 60g of HC mixture (R290/R600 a).

NetRefrigerationeffect: The net cooling effect's sensitivity to refrigerant weight is plotted in Fig. 2. The HC mixture was shown to be more effective as a refrigerant than either R134a or R600a alone. Additionally, it has been noted that low HC refrigerant charge results inresults superior to those achieved by the other two coolants. At -100 degrees Celsius, the RE provided by the HC combination is higher by 16.3%, 21.4%, 19.3%, and 52.98% compared to R600a(50g), R55g, R60g, and R134a. As can be seen, among the listed refrigerants, the HC mixture has the highest RE.

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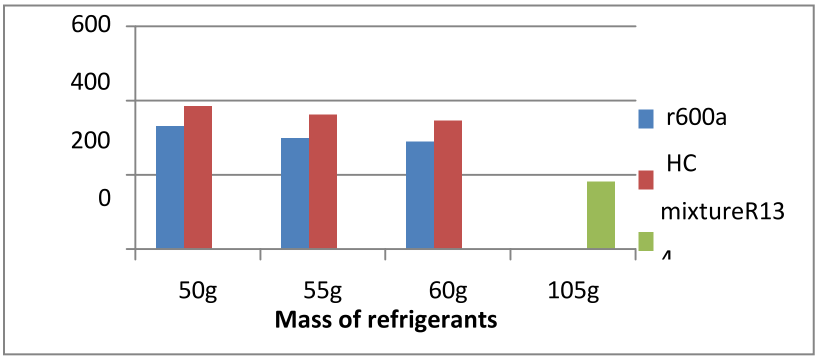

FIGURE 2. Net refrigeration effectVs massif refry grants R600a,HC mixture(R290/R600a–50/50bywt%)and R134aat-10^{0}cevaporatortem prelatures

Compressorwork: Compressor workload fluctuations as a function of refrigerant weight are depicted in Fig. 3. It was discovered that the HC mixture requires more effort from the compressor than either R134a or R600a. It is also noted that the work of the compressor is increased by the HC mixture due to its higher discharge pressure than the other two refrigerants. At -100 degrees Celsius, the RE from the HC mixture is 9.4 percent higher than that from R600a (50 grams), R600a (55 grams), R600a (60 grams), and R134a (105 grams), in that order. As can be seen above, the mixture containing 50 g of HC needed less effort than the other refrigerant weights.

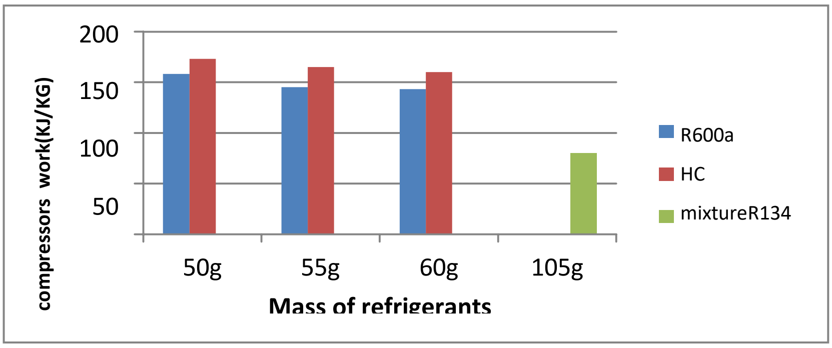

FIGURE 3. Compressor work Vs mass of refrigerants R600a, HC mixture (R290/R600a–50/50bywt%) and R134aat-10^{0}c evaporator temperatures

Coefficientofper romance: Changing performance coefficients as a function of refrigerant mass are depicted in Fig. 4. Higher RE of HC mixture enhances COP than R600, and it was shown that the COP is highest at 50g of HC mixture compared to R600a. A 50 g HC combination yields 6.2% more than R600a at -100 °C, although the cop of R134 is higher since its compressor work is less.

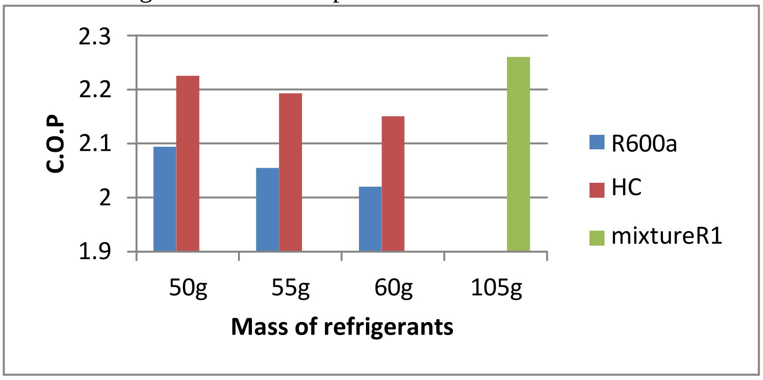

FIGURE 4. COP VsmassofrefrigerantsR600a,HC mixture(R290/R600a–50/50bywt%)andR134aat-10^{0}cevaporatortemperatures

Powerconsumption*:* Power usage shifts as a function of refrigerant mass are depicted in Fig. 5. It has been observed that the HC combination uses less energy than the R600a. It took 1.731 kW to cool off 60 g of R600a. R134a, in contrast to the HC mixture and R600a, required less energy to operate.

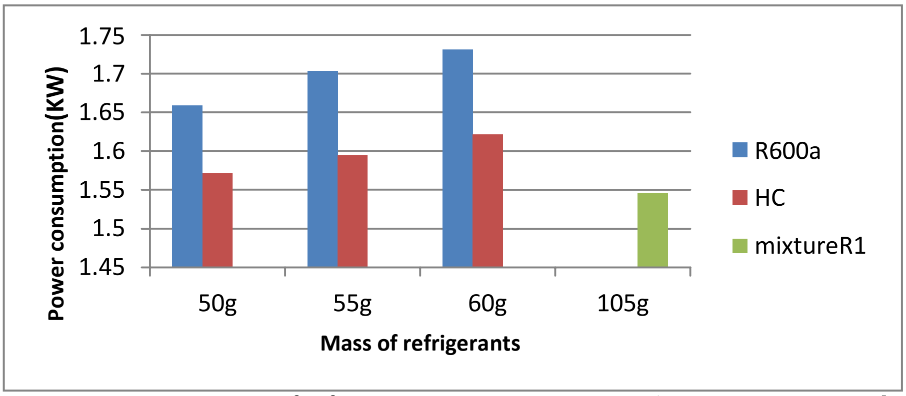

FIGURE 5. Power consumption Vs Mass of refrigerants R600a, HC mixture (R290/R600a– 50/50 bywt%) and R134a at-10^{0}c evaporator temperatures

Time taken*:* Time fluctuations relative to refrigerant mass are depicted in Fig. 6. It is evident that the 50 g HC combination required the least time (32.2 minutes) to deliver the performance of the system compared to the other refrigerant masses. However, the next recommended amount of R600a is 50 grams.

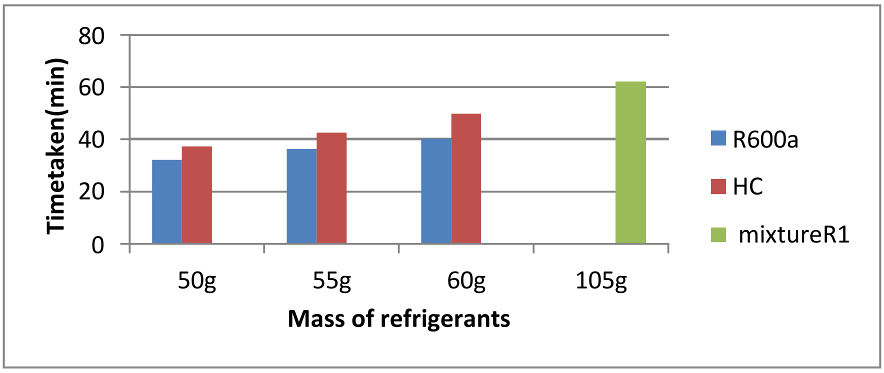

FIGURE 6. Time taken Vs mass of refrigerants R600a, HC mixture (R290/R600a–50/50 bywt%) and R134aat-10^{0} evaporators temperatures Heat rejected a condenser

Heat rejection in the condenser varies as a function of the amount of refrigerants present, as depicted in Fig. 7. R134a has the lowest heat rejection in the condenser, at 261 KJ/Kg, compared to the other refrigerants. The efficiency of a refrigeration system improves in proportion to the amount of heat rejected by the condenser. The largest measured condenser heat rejection was achieved with 50 g of HC mixture, compared to the other refrigerant masses.

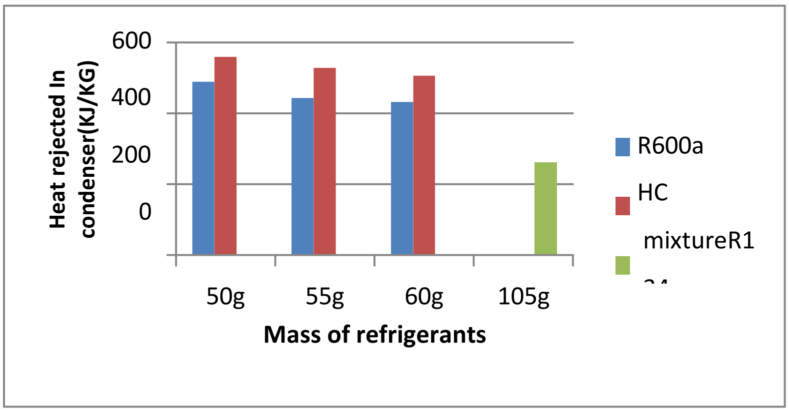

FIGURE 7. Heat rejectedincondenserVsMassofrefrigerantsR600a,HCmixture(R290/R600a–50/50bywt%)and R134aat-10^{0}cevaporatortemperatures

Energymeterreadings: Fig.8 depicts the fluctuations in energy meter readings as a function of the mass of refrigerants used. The R134a refrigerant clearly has the highest energy consumption, with a rating of 0.15 KWH. The higher the reading on the energy meter, the more greenhouse gases are released into the air. Therefore, it is observed that R600a emits very little energy into the environment.

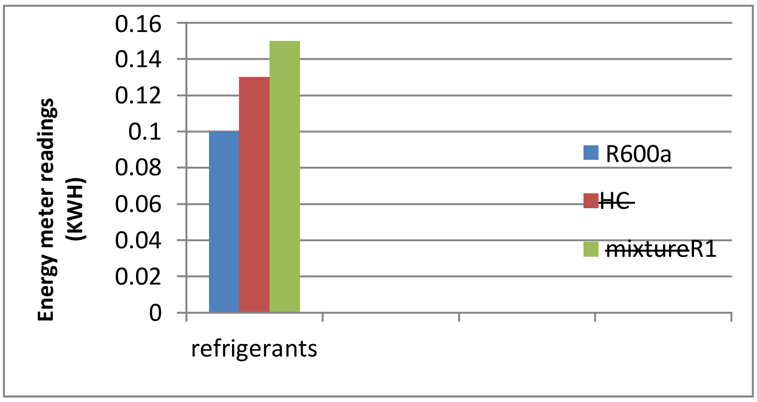

FIGURE 8. Energy meter readings Vs refrigerants R600a, HC mixture(R290/R600a – /50bywt%) and R134aat-10^{0}c evaporator temperatures

5. CONCLUSION

In light of the aforementioned,For 50g, 55g, and 60g samples, the HC mixture's cooling impact is 16.3%, 21.4%, and 19.3% higher than the R600a. In comparison to 105 g of R134a, the HC mixture is 52.9% more potent.For 50g, 55g, and 60g, the HC mixture compressor work is 9.4%, 13.7%, and 11.8% greater than the R600a, respectively. The HC combination weighs in at 53.7% more than 105 g of R134a.The COP of the HC combination is 6.25 percent greater than the R600a at 50 grams, 6.7 percent higher at 55 grams, and 6.4 percent higher at 60 grams. In comparison to 105 g of R134a, the HC combination is 1.54% less dense.For the 50g, 55g, and 60g masses, the HC mixture's power consumption is 5,5, and 6,77% and 6,78% lower than the R600a, respectively. The 105 g of R134a refrigerant is 1.6% more than the HC combination.The R600a for heat rejection in a 50g, 55g, and 60g HC mixture condenser is 14.1%, 18.9%, and 16.8% higher, respectively. In comparison to 105 g of R134a, the HC mixture is 53.2% more potent.The HC-mixture's energy meter registers at 30%, which is greater than the R600a. In comparison to 105 g of R134a, the HC mixture is 13.3 percent less dense.The HC combination has times that are 16.1% longer, 17% longer, and 22.3% longer than the R600a at 50g, 55g, and 60g, respectively. In comparison to 105 g of R134a, the HC mixture is 39.6 percent less expensive.The preceding data led to the conclusion that R134a, R600a, and HC mixes all share similar values for their performance parameters. As an alternative to R134a, it is suggested that 55 g of an HC mixture be used instead. The next viable option to R134a refrigerant uses could be 60 g of R600 a.

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