Performance Improvement of a Refrigeration System By Using Alternative Refrigerants R436a And R600a

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Abstract- *Now-a-days, by the use of refrigerants like chloro fluoro carbons and hydro fluoro carbons. the climatic temperatures of the earth are changing drastically due to the release of green house gases in to the earth's atmosphere which causes high global warming. Though R134a have zero Ozone Depletion Potential but a quiet higher Global Warming Potential . As per the recommendations from MONTREAL and KYOTO protocols , even new developed refrigerants like R134a should be phased out on or before 2040 due to their high GWP. Research shows that Hydrocarbons (HCs) are good alternative to existing refrigerants as they are not harm to the environment and the protective ozone layer. In the present work experiments conducted on vapour compression refrigeration system of domestic refrigerator using R600a and hydro carbon mixture R436a as refrigerants as they have zero ODP and very low GWP compared to the refrigerant R134a. Due to the higher value of Latent heat of HCs, the amount of refrigerant charge will be relatively lower than R134a. R600a and R436a refrigerants are tested individually and performance characteristics like RE, COP, Power consumption, Heat rejection in condenser are found and critical comparisons are drawn between these refrigerants. Results showed that the R600a refrigerant have higher over all efficiency than the R436a refrigerant .*

Keywords- Environmental friendly refrigerants, R600a (isobutane), HC mixture(R436a), 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 became available with the invention of CFCs and HCFCs. In 1930s , CFCs and HCFCs have been widely used in domestic refrigerators as refrigerants due to their suitable properties such as stability, non-flammability, non-toxicity, good thermodynamic properties ,which led to their common wide spread use by both consumers and industries across the globe, especially 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 reduction of green house gases emissivity. Hence in order to meet 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 R436a .these natural refrigerants are considerably cheaper than their significant alternatives.

II. SELECION OF REFRIGERANTS

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 -50^0 C to +50^0 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 R436a can also be used in place of R12. Isobutene R600 a is the most used hydrocarbon refrigerant in domestic refrigerators. In 21^{st} century, the use of isobutane and its mixtures was about 34% in domestic refrigerators and freezer at global level. Thus, HCs like R600 a and its mixture like R436a 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_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	$C_3H_8+C_4H_{10}$	49.3	3.7	A_3	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, a 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.

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.

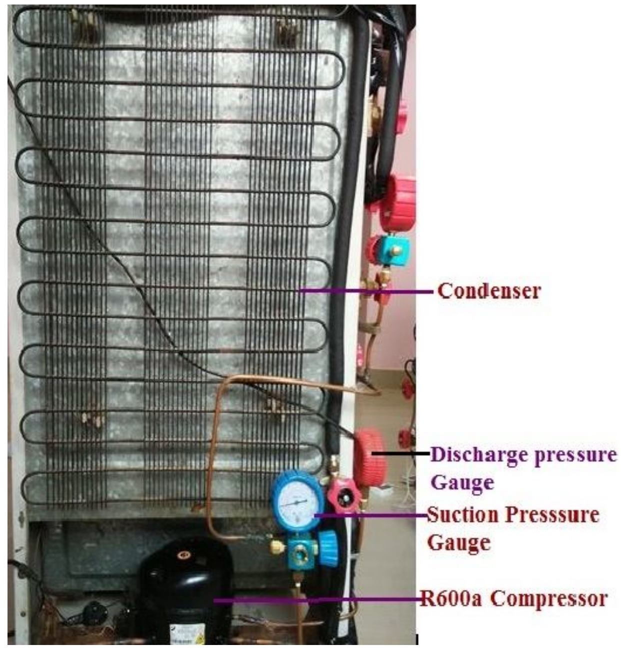

Figure.1 schematic diagram of VCRS system

For achieving better performance and long life reliability in domestic refrigerator and freezer, purity of R 134 a, R600 a and hydrocarbon mixture R436a was equal to 99.5%, that the purity of refrigerants which used in household refrigeration cycle should be more than 99.5% .

The following steps to be followed for the experimental analysis:

1. At first by using soap solution leakage tests are done to test the evaporator and condenser pressures and check purging daily for 8 hours and ensure that there are no leakages .
2. Charge R600a refrigerant in to the system with the help of charging unit and weight measuring device with +0.01gm accuracy.
3. Switch on the refrigerator and observed for 2 hour and then the readings of pressures and temperatures at each inlet and outlet sections of compressor, condenser and evaporator are noted.
4. The performance parameters are calculated by the obtained pressure gauge and temperature readings in the refrigeration system..
5. The actual refrigerating effect and cop of the refrigerated system are calculated .

6. The energy consumption of the compressor also measured by the energy meter readings.

Similarly refrigerant R436a also tested with different charges of 50g, 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..

IV.RESULT AND DISCUSSION

By adopting the above described test procedure energy consumption with R600 and R436a of defined charges are 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 R436a are discussed with respect to the parameters such as refrigeration effect, compressor work, energy consumption, COP, heat rejection ratio.

4.1.Refrigeration effect

Figure.2 shows the variations of refrigerating effect with respect to charge of the refrigerants. It was observed that the R600a has the highest refrigerating effect than the R436a. It is also observed that low charge of the R600a refrigerant gives better result. For -10^{0}c temperature 50g of R600a gives 14.02% higher RE than R436a.

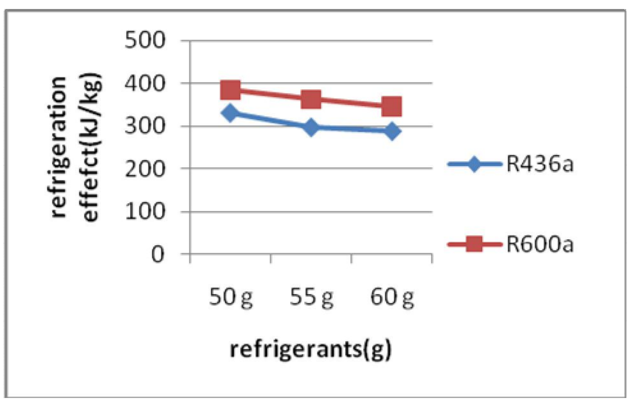

Figure.2 refrigeration Vs refrigerants

4.2.Compressor work

Figure.3 shows the variations of compressor work with respect to charge of the refrigerants. It was noted that the R600a has the highest compressor work. It is also observed that higher discharge pressure of R600a increases the work of the compressor. For -10^{0}c temperature R600a gives 8.6% ,12.1% and 10.6% higher RE than R436a (50g,55g, and 60g). From the above 50 g of R436a required lower work than the R600a refrigerant.

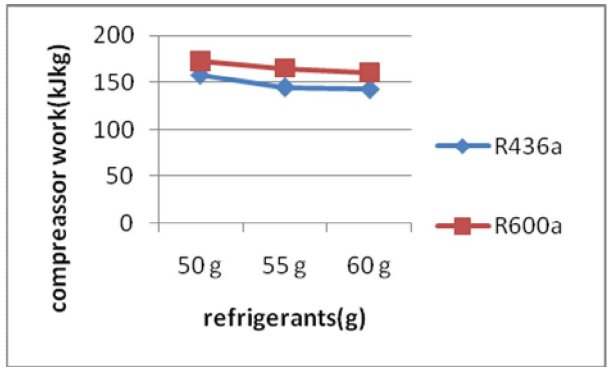

Figure.3 compressor work Vs refrigerants

4.3.Coefficient of performance

Figure.4 shows the variations of coefficient of performance with respect to charge of the refrigerants. It was noted that the 50g of R600a has the highest coefficient of performance than R436a. It is also observed that higher RE of R600a increases the COP than the R436a. For -10^{0}c temperature 50g of R600a gives 6.2% higher than R436a.

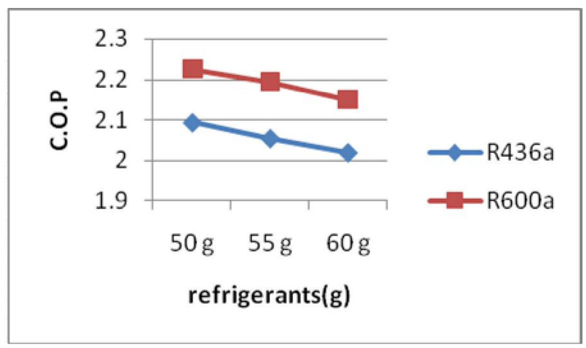

Figure.4 COP Vs refrigerants

4.4. Power consumption

Figure .5 shows the variations of power consumption with respect to the charge of refrigerants. It was noted that the R600a has consumed less power than the R436a . 60 g of R436a refrigerant had consumed 103.91 watts of power .

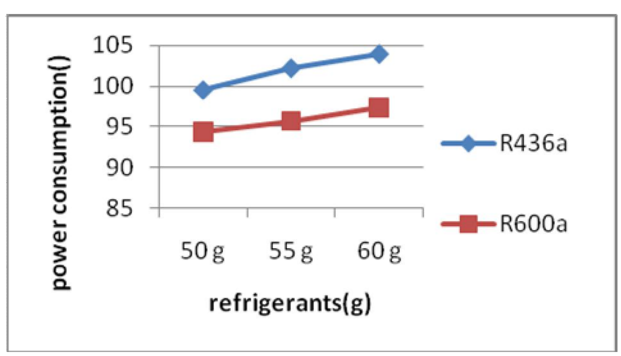

Figure.5 Power consumption Vs refrigerants

4.5.Time taken

Figure.6 shows the variations of time taken with respect to the charge of refrigerants. It is clear that among all the refrigerant masses, 50 g of R600a has taken 31 minutes of time to deliver the performance of the system which was less amount of time. Whereas 50 g of R436a is the next suited refrigerant.

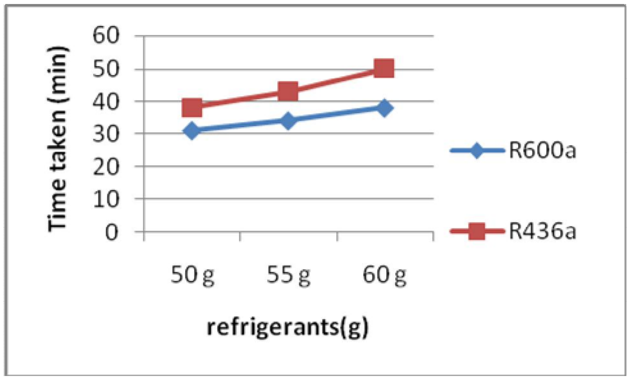

Figure.6 Time taken Vs refrigerants

4.6.Heat rejected in condenser

Figure.7 shows the variations of heat rejection in condenser with respect to the charge of refrigerants.. Greater the heat rejection in the condenser , higher the performance of the refrigeration system. It was observed that 50g of R600a has the highest amount of heat rejection in the condenser than the R436a refrigerant.

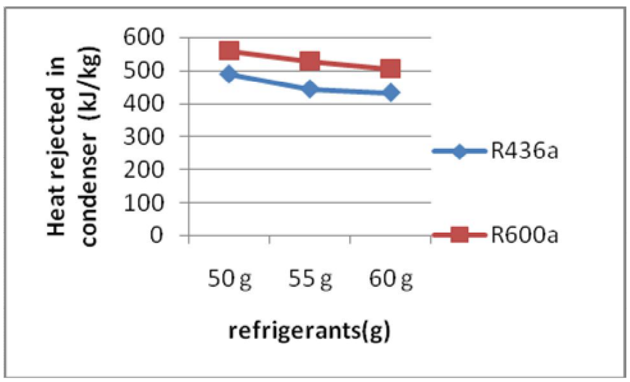

Figure.7 Heat rejected in condenser Vs refrigerants

V. CONCLUSION

In the present work experiments are conducted for R600a and R436a refrigerants of a vapor compression refrigeration system used for a 165 liters capacity

- Refrigeration effect of R600a has 21.4% increase than the R436a refrigerant
- Coefficient of performance of R600a ha 6.7% higher than the R436a refrigerant.
- Power consumed by the R600a has 6.77% lower than the R436a.

From all the above results, it was concluded that all the performance parameters of R436a and R600a refrigerants behave similar. It is recommended that 55g of R600a refrigerant may be used as the best refrigerant to improve the performance of the refrigeration system.

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