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COMPARATIVE STUDY OF R600a AND BLENDS OF (R600a /R1270) AS DOMESTIC REFRIGERANTS

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Abstract:

Millions of refrigeration systems, heat pumps and air conditioners all over the world operating with R134a have to retrofitted suitably in the event of the phase out due to high global warming depletion

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

1. *R600a/R1270(90/10by weight percentage)*
2. *R600a/R1270(80/20by weight percentage)*

The performance studies have been carried out with REFPROP database for property reference. The performance analysis raveled that the new refrigerant mixture performed better than that of R134a.It has been found that new refrigerant R600a/R1270(90/10by wt.%) and R600a/R1270(80/20by wt.%) blend has better performance that improved the COP of the system by5-12%and 9.7-15.6% higher than R134a.This is due to their higher refrigerating capacity than that of compressor power consumption. This mixture achieved lower freezer air temperature compared to R134a.The results of the present investigation have proved that the new alternative refrigerant R600a/R1270(90/10by wt.%) and R600a/R1270(80/20by wt.%) blend could be a better substitute for R134a.

Key Words: Refrigerator, REFPROP, R1270 & R600a.

1. Introduction:

The last seven decades, the CFCs and HCFCs have been used in the field of refrigeration and air conditioning due to their favourable characteristics. As per the agreement of Montreal and Kyoto protocol 1987 all CFC'S and HCFC'S must be phased out both in developed and developing countries. As per ASHRAE standard - 34 all HCFC should be phased out by 2030 .The Govt. of India, The Ministry of Environment and Forest (MoEF), emphasizing and giving indications on Environmental Impact Assessment (EIA). The Ministry has issued the Environmental Impact Assessment Notification, 2006, which makes environmental clearance mandatory for the development activities to identify, examine, assess and evaluate the likely and probable impacts of a proposed project (alternate refrigerants) on the environment and, thereby, to work out remedial action plans to minimize adverse impact on the environment. Usage of natural refrigerants for Air conditioning system may be a best option for effective utilization for eco-friendly atmosphere. Current research focus on development of new refrigerants to retrofit the existing R134a systems. Various alternative refrigerants are available to the conventional systems. But each one has its own merits and demerits. A theoretical analysis was implemented for the use of R134a, propane (R290) and selected mixtures of R290/R600a 60 % / 40 %, R290/R600a/R134a 40 %/30%/30% and R290/R600a 50%/50% in the ASHRAE standard cycle cooling (evaporation temperature: -23.3ºC, condensation temperature: 54.4°C, temperature of liquid and suction: 32.2ºC) using the thermodynamic properties of REFPROP 6.0, as recommended by Kim .The coefficient of performance of systems for commercial and domestic refrigeration is increased from 10 to 20% when using mixtures of hydrocarbons containing R600a and R290 Sekhar [1]. Fatouh and El Kafafy evaluated theoretically a mixture of hydrocarbons composed of 60% and 40% R290/R600 as a better drop-in replacement for domestic refrigerators based on HFC -134a under abnormal weather conditions, subtropical and tropical regions [2]. Lee and Su conducted an experimental study in the use of isobutene in a household refrigerator. The results showed that the coefficient of performance was comparable with that obtained by CFC12 and HCFC22 when used as refrigerants [3]. An theoretical analysis was developed for R134a, propane (R290) and selected mixtures (R290/R600a 60 % /40%, R290/R600a/R134a 40%/ 30 % / 30 % and R600a/R290 50%/50%) in the ASHRAE standard refrigeration cycle (evaporation temperature: -23.3ºC, condensation temperature: 54.4°C, temperature of liquid and suction: 32.2ºC) using the thermodynamic properties of REFPROP 6.0, as recommended by Kim [4]. M. A. Hammad has experimentally investigated the performance parameters of a domestic refrigerator with four proportions of R290, R600 and R600a are used as possible alternative replacements to the R12. An unmodified R12 domestic refrigerator was charged and tested with each of the four hydrocarbon mixtures that consist of 100% R290, 75%R290/19.1%R600/5.9%R600a, 50%R290/38.3%R600/11.7%R600a and 25%R290/57.5%R600/17.5%R600a. The investigated parameters are the refrigeration effect and energy consumption. The results show that the hydrocarbon mixture with 50%R290/38.3%R600/11.7%R600a is the most suitable alternative refrigerant which has COP which is 2.7% higher than the R12 [5]. B. Tashtoush, has experimentally investigated the drop in substitutes for R12 in domestic refrigerators by new HC/HFC (butane/propane/R134a) refrigerant mixture. It was found that the BPR80 (31.25%R600/31.25%R290/37.5% R134a) mixture gives performance characteristics very close to R12. The COP of BPR80 at a 100 W evaporator duty is 5.4% less than that of R12 and 0.8% less at a 350 W evaporator duty. These differences are due to the slightly higher compression power requirements of BPR80, and are considered too small to affect retrofitting [6]. A trial was performed by Rocca and Panno to replace R22 with new HFC refrigerants and the performance was compared with R–22. The plant working efficiency was first estimated with R–22 and then with three new HFC refrigerants, R–417a, R–422a and R–422d. The experimental results showed that R–22 has the least energy consumption among all the refrigerants under trial. Results also reveal that the three HFC refrigerants can replace R–22 without any change in lubricant or without any modification in the system and the accessories. These refrigerants also provide the safe and reliable working conditions. The results also verified that despite these advantages, the performance of the new tested HFCs was not as efficient as with R–22[7]. Llopis replaced R–22 by two refrigerants HFC–422a and HFC–417b in medium and low evaporating temperatures. The test was conducted in a two stage refrigerating plant equipped with subcooling. The evaporator and condenser temperature range were –31^{O}C to 17^{O}C and 30^{O}C to 48^{O}C respectively. The experimental results showed that with the use of new refrigerants, the refrigerant mass flow rate need to be incremented. The new refrigerants also lead to lower specific refrigerating effect that tends to reduced cooling capacity. This reduction in the plant capacity was much more than expected from the theoretical analysis [8]. Refrigerant selection involves balancing conflicting requirements such as: ability to transfer heat, chemical stability, and compatibility with compressor lubricants, flammability, and toxicity. Akash and Said studied the performance of mixed refrigerant from local market (30%propane, 55% n-butane and 15% isobutene by mass) as an alternative refrigerant for CFC-12 in domestic refrigerator with masses of 50g, 80g and 100g [9]. R. N.

Richardson, investigated the performance of hydrocarbon refrigerant mixture of R290/R600a in a VCR system. It is shown that the 56%/44% mixture has a COP greater than that of R12 throughout the range of temperatures which have been investigated. Mixture of 50%R290 and 50%R600a has very similar saturation characteristics to R12 but COP which would seem to improve with the proportion of R290 [10]. M. Mohanraj have studied experimentally the drop in substitute for R134a with the environment friendly, energy efficient hydrocarbon (HC) mixture which consists of 45% HC290 and 55% R600a at various mass charges of 50g, 70g and 90g in domestic refrigerator. The results showed that the higher COP of 8.82%, 11.42% and 12.67% respectively for -15OC evaporator temperature and 45OC condensing temperature [11]. The work has been undertaken to investigate the performance of the selected alternative refrigerants in a vapour compression refrigerant system. The refrigeration system variables considered for this investigation are evaporating temperature, and refrigerating capacity.

2. Experimental Setup:

A domestic refrigerator which consumes 1400KW for a year was selected for performance evaluation of various refrigerants such as R134a, R600a and hydrocarbon mixtures of isobutene and propylene in various ratios. The refrigerator functions with a reciprocating compressor and performance is evaluated in terms of COP of refrigerator, refrigeration capacity, Time required for the expected cooling effect with the same mass of various refrigerants.

The refrigerator has following specifications and it is maintained for the whole setup.

Gross volume	: 165L
Base refrigerant	: R12.
Mass of refrigerant	: 130g
Speed of compressor	: 2850 rpm
Type of compressor	: Reciprocating
Rating	: 1.1amp/160-250 volt
Power of compressor	: 1/8 HP

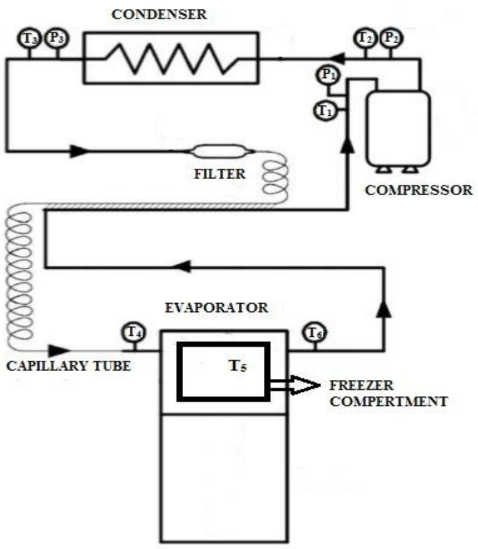

Figure:1 Schematic Diagram of a Domestic Refrigerator.

The performance study includes measurement of temperature, pressure values at various places in the VCR system viz., compressor inlet, outlet and evaporator inlet and outlet in accordance with the performance calculation. The vapour compression system is initially cleaned by nitriding the entire system and the evacuation of the system is carried out with the help of a vacuum pump for nearly 30 min and then the refrigerant is charged with the help of the charging system. The pressure and temperature values at various points of the setup were noted down at various time intervals.

1. T_1- Compressor Inlet Temperature
2. T_2-Compressor Outlet Temperature
3. T_3-Condenser Outlet Temperature
4. T_4-Evaporator Inlet Temperature
5. T_5-Freezer Compertment Temperature
6. T_6-Evaporator Outlet Temperature
7. P_1-Compressor Inlet Pressure
8. P_2-Compressor Outlet Pressure
9. P_3-Condenser outlet pressure

The various refrigerants that were used in the experimental setup are listed and shown below.

- R134a
- R600a
- Blend 1(90%R600a & 10%R1270)
- Blend 2 (80%R600a & 20%R1270)

3. Experimentation:

Blends are used in the proportions of (80% of R600a / 20% of R1270) and (90% of R600a / 10% of R1270) by mass fraction and they were chosen using REFPROP software.

The vapour compression system is initially cleaned by nitriding the entire system and the evacuation of the system is carried out with the help of a vacuum pump for nearly 30 min and then the refrigerant is charged with the help of the charging system. The pressure and temperature values at various points of the setup were noted down at various time intervals.

The performance of the inserted refrigerant is calculated using conventional theoretical COP calculation procedure, then the refrigerant was sucked out, tubes were dried and next refrigerant is inserted in the setup. The same procedure is repeated for various refrigerants and their performance were calculated in terms of COP, refrigeration effect, time requirement and they are compared with each other. Among then the best suited refrigerant was calculated.

4. Results and Discussion:

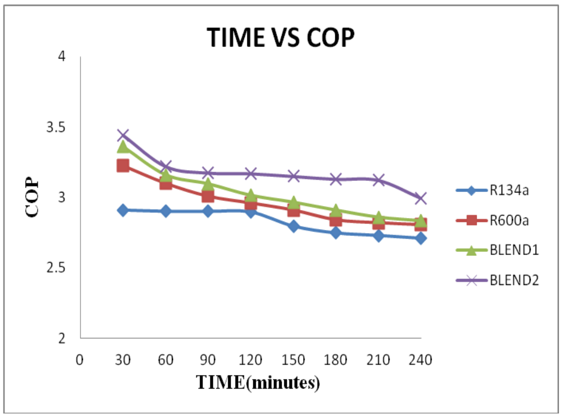

Figure 2: Variation of Cop with respect to Time

The data was collected manually every fifteen minutes and at the same time the temperature and pressure of each point were recorded for four different refrigerants in order to investigate the performance of the refrigerator

From the above graph it is clear that the coefficient of performance of the blend is more when compared to that of R134a. This is due to the thermodynamic properties of the refrigerant. When the time increase the cop of the refrigerants decrease. These occur because of the reduced space temperature and less mass flow rate of the refrigerant in the evaporator coil. The cop of the blend1 and blend2 refrigerant mixture is 5-12%and 9.7-15.6% higher than that of R134a.

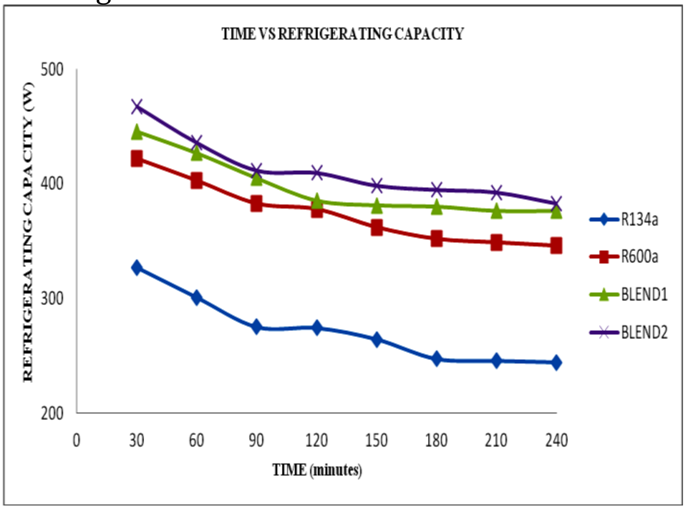

Figure 3: Variation of Refrigerant Capacity with respect to Time

Refrigeration effect of refrigerants are plotted for various time intervals and compared with various refrigerants' refrigerating capacity. on comparing the refrigerating capacity with time, it is noted that the refrigerating capacity is high at the initial level of the refrigerator system .In order to absorb more amount of heat from the freezer compartment higher mass flow rate is need.

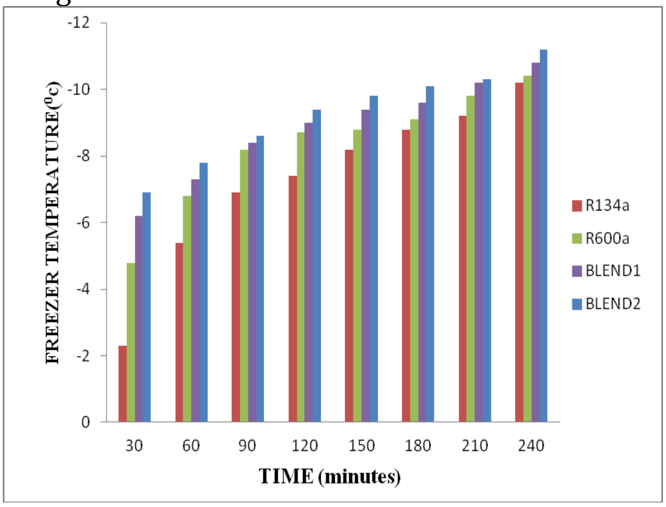

Figure4: Comparison of Freezer Temperature Vs Time

From the graph it's observed that R134a give -9.8 were as blend2 give -11.2 after four hours. so it clearly state that blend 2 gives minimum freezing temperature compared to R134a

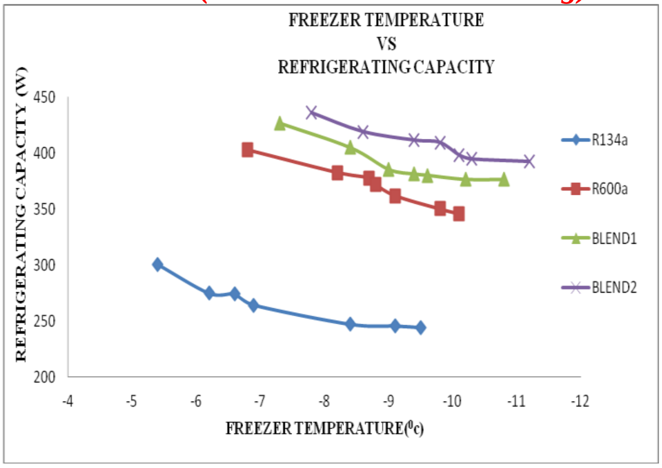

Figure 5: Freezer Compartment Temperature vs. refrigerating capacity

Figure shows the observed values for R134a and different mixtures for temperature vs refrigeration capacity from the graph we can identify that blend 2 has more refrigeration capacity for temperture than basic refrigerant and other mixtures.

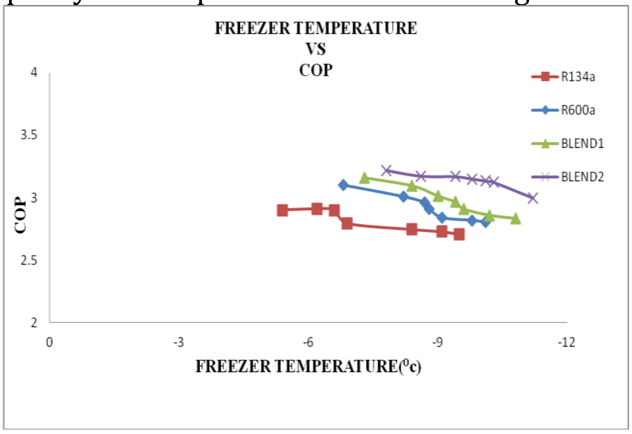

Figure 6: Freezer Compartment Temperature Vs Cop

Figure the observed values of cop for R134a ,R600a and mixed refrigerants at different temperatures. COP of the mixed refrigerant shows more cop compared to refrigerant r134a.

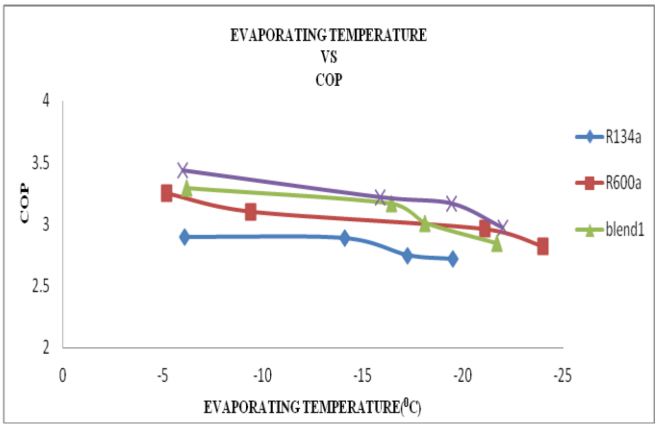

Figure 7: The Variation of Coefficient of Performance for Various Evaporating Temperature

The figure shows the variation of coefficient of performance for various evaporating temperature. It is observed that evaporating temperature increases the coefficient of performance also increase. This due to increased mass flow rate of the refrigerants and possibly better heat transfer properties.

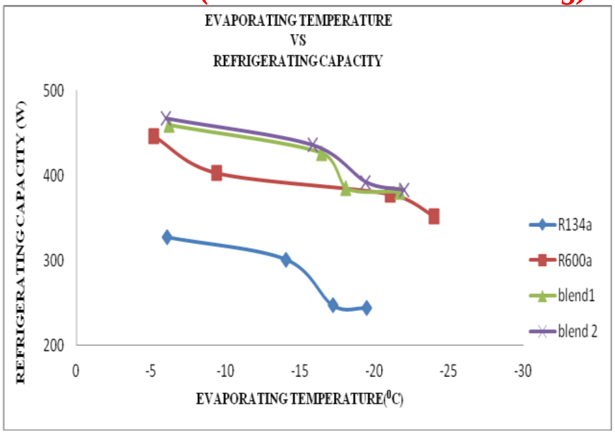

Figure 8: Variation of Refrigerating Capacity for Various Evaporating Temperature

The figure shows the variation of refrigerating capacity for various evaporating temperature. It is observed that evaporating temperature increases the refrigerating capacity also increase .this due to the increased mass flow of the refrigerants as the evaporating temperature increase the refrigerating capacity of blend 2 and blend 1 is 30-37% and 28-34% higher than R134a for the range of evaporating temperature.

5. Conclusion:

The GWP is the major driving force to phase out R134a. Based on the extensive literature survey, it was found that the R600a/R1270 refrigerant blends could be a viable alternative to R134a and their performance based on experiments, were discussed on the above investigations and the following conclusions are drawn.

Of all four refrigerants considered R134a, R600a, Blends of R600a & R1270 it was found that blend of R600a & R1270 in the proportions of 80 and 20 by mass fraction could be considered for medium and high evaporator temperature applications.

From the experimental study it has been observed that the refrigerating capacity and COP of the selected refrigerants increases with increase in evaporating temperature and decreases with increasing condensing temperature. The refrigerating capacity and COP of R600a/R1270 were higher than that of R600a and R134a for the range of same operating conditions.

The power consumed by the compressor was lower with the refrigerants R600a and R134a for the range of operating conditions. The COP of the refrigerants R134a, R600a was lower than R600a and R134a. All the alternative mixtures showed a reduction in charge due to their low liquid densities. Every mode of mixed refrigerants yields higher COP than R134a and it was made clear with two different compositions of R600a/R1270.It was found that over all Coefficient of Performance of the blend isobutane80%/propylene20% increases by 29.8% when compared with R134a 21% when compared with R600a.

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