EXPERIMENTAL ANALYSIS OF HYDROCARBON MIXTURES AS THE NEW REFRIGERANT IN DOMESTIC REFRIGERATION SYSTEM

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Abstract - Conversion of R134a systems to eco-friendly ones will be a major thrust area for refrigeration sector in the present day. As and when an existing system of R134a has to be recharged it is suggested to retrofit the system with new/natural and alternative refrigerants. Presently in market some hydrocarbon mixtures and pure hydrocarbons are available to replace R134a. But what will be ratio and mass fraction to be used for better and safe performance of the system is only given by some researchers. This investigation focuses on mixture ratio of pure hydrocarbon R290 and R600a uses in 200 liter domestic refrigeration system by certain changes in condenser and capillary. The outcome of this work is 80g mixture of R600a/R290 (60/40 by wt%) give better performance than 80g mixture of R600a/R290 (70/30 by wt%). COP of R600a/R290 (60/40 by wt%) mixture is higher in the range 22%-26.3% than mixture R600a/R290 (70/30 by wt%) for capillary of 3.5m length and 0.036 inches diameter. During the experiments it is found that 0.036 inches dia. capillary is more suitable as expansion device than 0.031 inches dia. capillary at all length . It is also find out that by increasing the length of capillary in the system hydrocarbon mixture give better results. The R600a/R290 (60/40 by wt%) mixture can be consider as a drop- in replacement refrigerant for HFC134a.

Index Terms - R600a/R290;HFC;domestic refrigerator; capillary.

1 INTRODUCTION

Domestic refrigerators use R12 and R134a as refrigerants due to these gases excellent thermodynamic properties. According to Montreal and Kyoto protocols, R12 should have been phase out in 2010 and he consumption of R134a must be reduced. The reason for R12 phase out is its ODP effect, and R134a reduction is its high GWP effect. From the environmental, ecological and health point of view it is urgent to find some better substitute for HFC refrigerants [1]. The Kyoto Protocol of the United Nation Framework Convention on Climate Change [UNFCCC] calls for reductions in emissions of six categories of greenhouse gases, including hydroflurocarbons (HFCs) used as refrigerants [2].

Refrigerators are identified as major energy consuming domestic appliance in house hold environment [3] many researchers have reported that hydrocarbon mixed refrigerants is found to be an energy efficient and environmental friendly alternative option in domestic refrigerators. Akash and Said[4] experimented with (LPG) {composed of R290, R600 and R600a in the ratio of 30:55:15 by mass} as an alternative to R12 in domestic refrigerators at various mass charges 50,80 and 100g. The results reported that 80g of LPG showed the best performance compared to that of R12. Jung et al. [5] experimented with R290/R600a (in ratio of 60:40 by mass fraction) as an alternative to R12 in 299 and 465 liter domestic refrigerators and reported that COP and energy efficiency were improved by 2.3 and 4%,respectably. Wongwises and Chimres[6] presented an experimental study on the application of a mixture of Propen , Butane and Isobutane to replace HFC 134a in a domestic refrigerator. The result showed that a 60% / 40% propen/butane mixture was the most appropriate alternative refrigerate. Mani and Selladurai[7] performed experiments using a vapor compression refrigeration system with the new R290/R600a refrigerant mixture as a substitute referent for R12 and HFC134a. According to the results of their experiments, the refrigerant R290/R600a had a refrigerating capacity 19.9% to 50.1% higher than that of R12 and 28.6% to 87.2% than that of R134a. The R290/R600a blend's performance coefficient (COP) is improved by 3.9-25.1% compare to that of R12 at lower evaporating temperature and by 11.8-17.6% at higher evaporating temperatures.

The refrigerant R134a had a slightly lower COP than R12. The literature review brings out the fact that many researchers [1-7] have studied with different hydrocarbon refrigerant mixtures as alternative to R12 and R134a in domestic refrigerators.

The present paper investigate possibilities of using 80g HCM of mixture R600a/R290 (70/30by wt.%) and mixture R600a/R290 (60/40by wt.%) in vapor refrigeration system. The objective of the study is to explain the possibility of using above mentioned HCM with accurate mixture composition and capillary design in a 200 liter domestic refrigerator which use presently R134a as a refrigerant. The influence of ambient temp. on the performance characteristics of the system under continues and cyclic running operation mode at different evaporating temperature maintained in calorimeter with 35°C ambient temperature have been studied.

2 EXPERIMENTAL APPRATUS

An experimental setup of vapor compression refrigeration system was built up to investigate the performance 80g R600a/R290(70/30 by wt %) mixture refrigerant and 80g

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R600a/R290 (60/40 by wt %) mixture refrigerants. Fig. 1 shows the schematic diagram of the experimental setup. It consisted of two loops. A main loop was composed of compressor, condenser a filter-drier, expansion valve and calorimeter and second loop was consisted evaporator instead of calorimeter with all other main equipments.

2.1 Compressor
Hermetically sealed reciprocating type compressor with deep frizzing capacity for 200 liter refrigerator recommended for R134a refrigerant .Rated motor HP is 1/83 & fan blade is 9 inches diameter.

2.2 Condenser
A forced convection Air- cooled type having size 10x10 square inches for single pass copper tubing size 1/4 inches, having thin aluminum sheet attached crosswise for improvement of heat dissipation.

2.3 Expansion device
A capillary tube of size 3.5 m and 3 m length and dia .036 inches and .031 inches alternatively used for assessing and optimizing of capillary for above mentioned mixture.

2.4 Calorimeter
A calorimeter design for measuring refrigerating effects of system it consisted a cooling coil of 5/16 inches diameter, L=12 feet, a heating coil attached with watt meter, temperature measuring device, a stirrer rotted by motor and all consisted in ethylene glycol in main loop. A evaporator of 200 liter refrigerator connected in secondary loop for measuring load & no load measurements of system.

With all these 9 thermocouples of ranges -50°C to 80°C with 0.1°C accuracy fitted at inlet and outlet of all major equipments. Two pressure gauges one compound pressure gauge measure from -30 psi to 500psi and one normal pressure gauge measured form -30psi to 150psi fitted at compressor discharge and suction respectively .

A supply energy meter also used to calculate energy consumption in KWhr. and a watt meter connected with compressor to measure compressor work at different evaporating temperature.

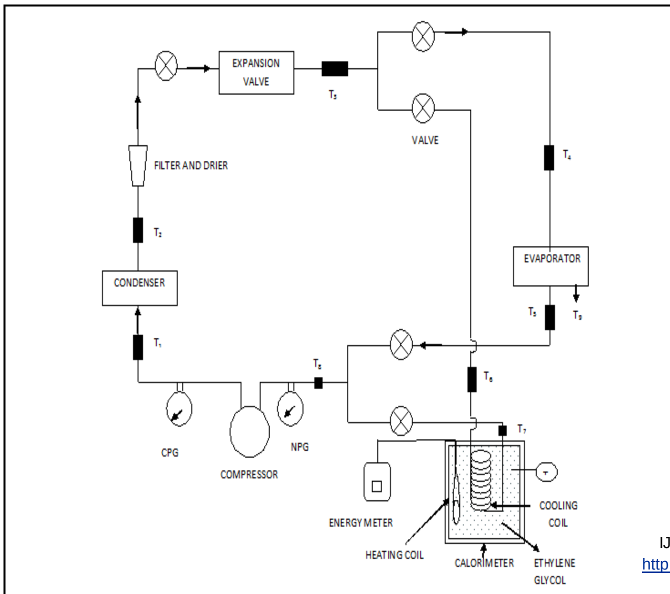

Fig 1: Line Diagram Of The Set-Up

3 Experimental Procedure
The objective of the study was to compare the performance of refrigerator for different hydrocarbon refrigerant mixtures in terms of refrigerating capacity (RC), compressor energy consumption, COP and pull down test on domestic refrigerating machine when its retrofitted for hydrocarbon mixture. The refrigerant was charged after the system have been evacuated, the working fluid 80g R600a/R290 (70/30 by wt %) and R600a/R290 (60/40 by wt %) used alternatively. The reading was taken after the system had been reached steady state condition. Pull down test on load carried out by connecting calorimeter in refrigerator as per the procedure followed by M.Mohanraj et al. [8]. The actual refrigeration capacity and COP of the refrigerator were calculated as per the procedure followed by K. Mani and V. Selladurai [7]. The heater load adjusted by a dimmer stator to maintain a constant evaporating temperature of calorimeter (-5,-2.5, 0, 2.5, 5, 10 degree C) to calculate COP, RE etc. The energy consumption of the system measured by separate energy meter in KWhr. The length and size of capillary tube optimization also carried out by changing capillary of different length & diameter during test. Pull down test / RE /COP measurement are carried out initially 80g mixture of R600a / R290 (70/30 by wt %) 3.5 meter length of .036 inches dia. and 0.031 inch dia. respectively , similar for 3m length of .036 and .031 inches dia. capillary.

After the system evacuated and new mixture of 80g R600a/R290 (60/40 by wt %) was charged with the help of weight measuring device used with 1g accuracy and find out RE & COP of the system temperature and pressure at different location were recorded after every 10 min. intervals. The energy consumption of the compressor is measured separately by Volt/Ammeter meter and multiplied by power factor and also measured by wattmeter. The measured value were used to study the performance characteristics of the refrigerator.

4 Result and Discussion
Experimental results obtained for pull down test with respect to time in min. and performance of the parameter such as refrigerant capacity, compressor energy consumption, COP etc. analysis for HC mixture R600a / R290 (70/30 by wt%) and R600a/R290 (60/40 by wt %) with respect to evaporating temp. between -5°C & 10°C Fig. Shows the experimental results at T=35°C ambient temperature.

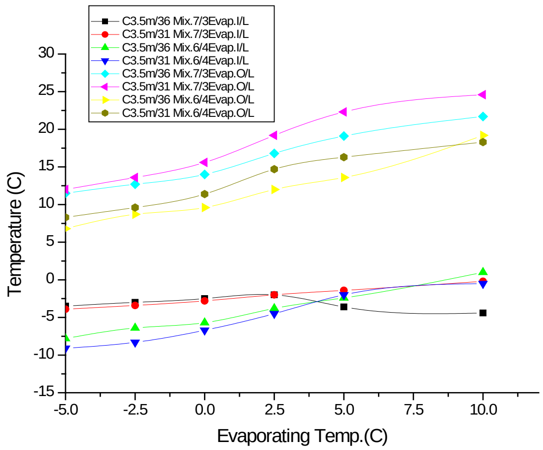

Fig.2 Variation of evaporator inlet and outlet temp. with evaporating temp. (calorimeter temp.) for capillary 3.5m length and dia.0.036 & 0.031 inches Mix.7/3 is R600a/ R290 (70/30 by wt %) & mix.6/4 is R600a/R290 (60/40 by wt.%).

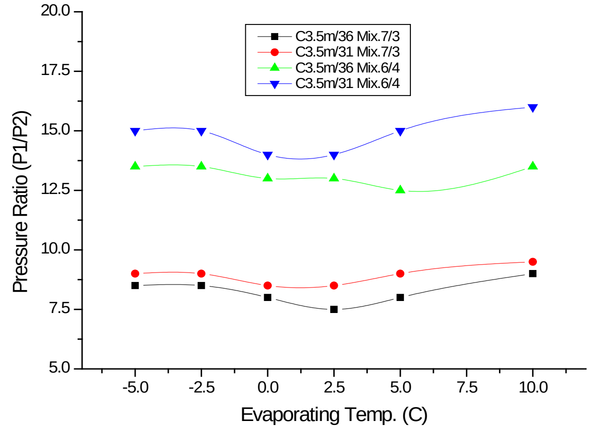

Fig.4 Variation of compressor press. ratio (P1/P2) Discharge /Suction with evaporating temp. for capillary 3.5m length and dia. 0.036 inch (36)& 0.031 inch(31). Mix.7/3 is R600a/ R290 (70/30 by wt %) & mix.6/4 is R600a/R290 (60/40 by wt.%).

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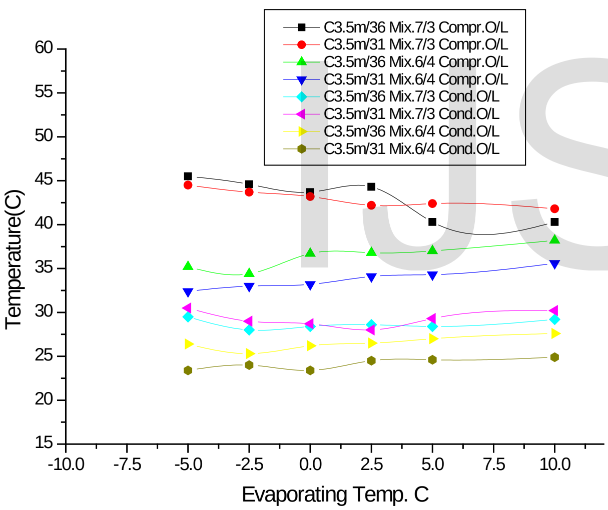

Fig.3 Variation of compressor inlet and outlet temp. and condenser inlet and outlet temp. with evaporating temp. for capillary 3.5m length and dia.0.036 &0.031 inches. Mix.7/3 is R600a/ R290(70/30 by wt %) & mix.6/4 is R600a/R290 (60/40 by wt.%).

4.1 Pull down test

Pull down test is the time required to reduced the evaporator tamp. (Calorimeter temp.) from ambient temp. to the desired temp. according to ISO 8187 (10). Pull down test were carried out at 28°C (calorimeter temp.).

It was observed that pull down time on load condition is about 140 min. was required to reach from 28 degree C to desired temperature -2.5°C of ethylene glycol for mixture R600a/ R290 (70/30 by wt %) when capillary of 3.5 meter length & .031 inches dia is used. Capillary 3.5 m. length & .036 inches dia. reaches the desired temp. in 160 min. and capillary of 3 m length & .036 inches dia. also take same time. But capillary of 3m length and .031 inches dia. reaches the desired temp, in 140 min. Its shows that capillary of .031 inches dia. give better pull down time whatever length 3.5 m or 3 m used. This is carried only for one HC mixture that is R600a/R290 (70/30 by wt %).

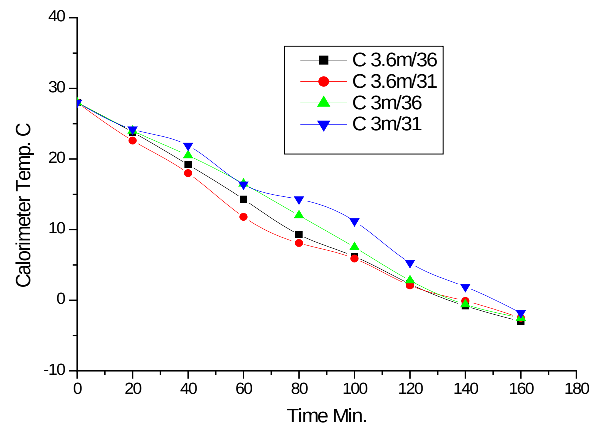

Fig.5 Pull down time vs. calorimeter temp. at 35 degree ambient temp. for

R600a/R290 (70/30 by wt.%) and capillary of 3.5m&3m length and dia. 0.036 (36)& 0.031 (31) inches(continuous running test).

4.2 Refrigerating capacity

Fig - 6 shows the variation of refrigerating effect against the evaporating temperature at 35°C ambient temperature.

It was observed that the refrigerant mixture R600a/R290 (60/40 by wt %) had the higher R.E. than R600a/R290 (70/30 by wt %) by 37% to 49%. HC mixture R600a/R290 (60/40 by wt %) had refrigerating effect higher by 18% - 32% in capillary 3.5 m. length and .036 inches dia. than capillary 3.5 m length and .031 inches dia.

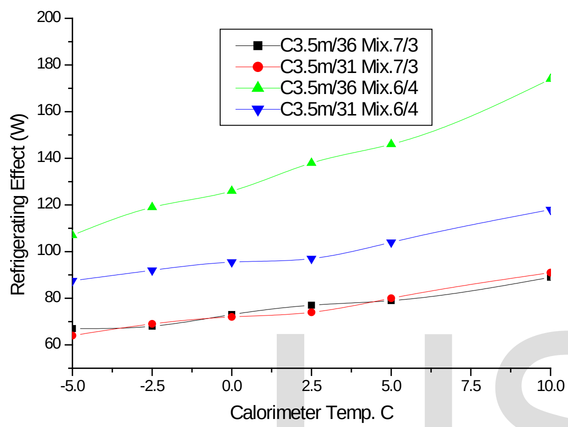

Fig.6 Variation of refrigerating effect with evaporating temp. for capillary 3.5m length and dia. 0.036 (36) &0.031 (31) inches. Mix.7/3 is R600a/ R290 (70/30 by wt %) & mix.6/4 is R600a/R290 (60/40 by wt.%).

4.3 Compressor Energy Consumption

Fig. 7 shows that the energy consumption by the compressor increase as the evaporating temperature increases.

Test results shows that the energy consumed by the system with R600a/R290 (60/40 by wt %) mixture was higher by 19.6% - 30.6% than mixture R600a/R290 (70/30 by wt %) . Capillary 3.5 m length and .036 inches dia. consumed more work than capillary 3.5 m length and .031 inches dia.

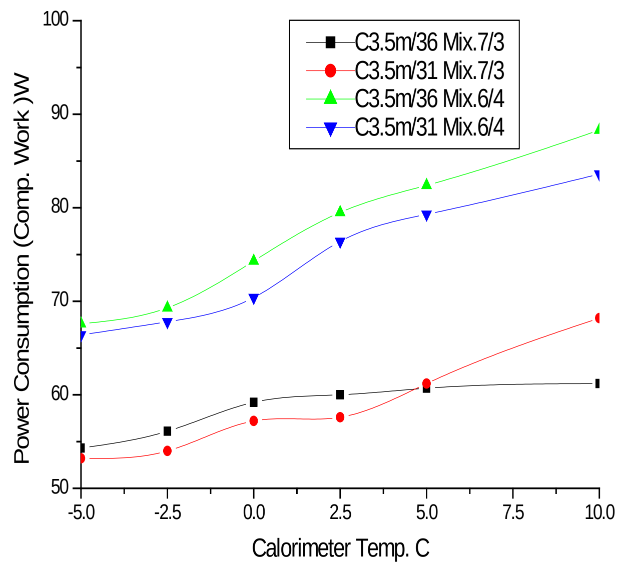

Fig.7 Variation of compressor work with evaporating temp. for capillary 3.5m length and dia.0.036 (36) &0.031 (31) inches. Mix.7/3 is R600a/ R290 (70/30 by wt %) & mix.6/4 is R600a/R290 (60/40 by wt.%).

4.4 Coefficient of performance (COP)

Fig 8 shows the COP increases as the evaporating temp increases. COP For R600a/R290 (60/40 by wt %) and R600a/R290 (70/30 by wt %) with different dia. of 3.5m length capillary shows in fig 8.

It was observed that the COP of R600/R290 (60/40 by wt %) mixture was 22% - 26.3% higher than R600a/R290 (70/30 by wt %). COP of R600a/R290 (60/40 by wt %) mixture higher 17%-28% with capillary 3.5 M length and .036 inches dia. than capillary 3.5 M length and .031 inches diameter.

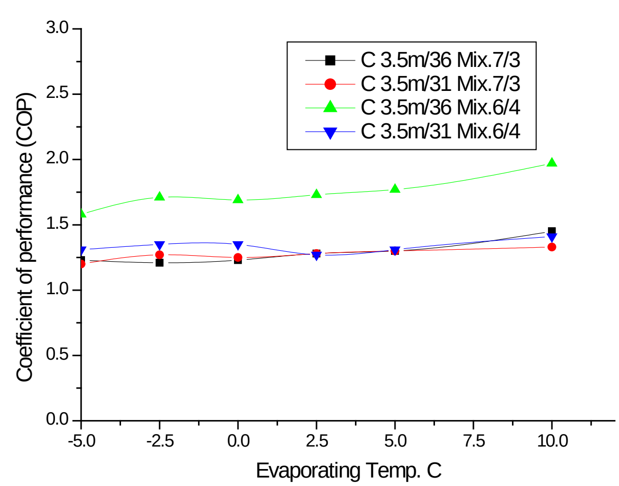

Fig.8 Variation of COP with evaporating temp. for capillary 3.5m length and dia.0 .036 (36) &0.031 (31) inches. Mix.7/3 is R600a/ R290 (70/30 by wt %) & mix.6/4 is R600a/R290 (60/40 by wt.%).

5 Conclusions

A performance analysis done on vapor compression refrigeration system with the HC refrigerant blends to substitute refrigerant HFC134a (Retrofitting).

Refrigerating effect of R600a/R290 (60/40 by wt %) mixture was higher in the range 26.8%-37% in lower evaporating temp. and higher 22.8% -48.8% in higher evaporating temp. than R600a/R290 (70/30 by wt %) for 3.5m length capillary .031 inches dia. and .036 inches diameter.

Energy Consumption of R600a/R290 (60/40 by wt %) mixture was higher in the range 19.6% - 30.7% than R600a/R290 (70/30 by wt %) mixture for capillary 3.5 M length and .036 inches dia.

COP of R600a/R290 (60/40 by wt %) mixture was higher in the range 22%-26.3% than mixture R600a/R290 (70/30 by wt %) for Capillary 3.5 M length and .036 inches dia. from lower evaporating temp. to higher evaporating temperature.

During the experimental test R600a/R290 (60/40 by wt %) were found to be suitable with Capillary 3.5m length and .036 inches dia. than R600a/R290 (70/30 by wt %) .Pull down time slightly higher for capillary of .036inches dia. than .031inches diameter. However care should be taken when using R600a/R290 HC mixture as a retrofitted in present refrigeration system of R134a due to HC mixture are flammable.

So further investigation is required to find out exact length and mass of HC mixture for capillary of 0.036 inches diameter.

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