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PERFORMANCE OF DEEP FREEZER BY USING HYDROCARBON BLENDS AS REFRIGERANTS

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ABSTRACT

This paper projects experimental study carried out for evaluating performance parameters of deep freezer when three ratios of Propane [R290] (pure 100%), Iso -butane [R600a] (pure 100%), R600a (50%) + R290 (50%), R600a (20%) + R290 (80%), R600a (80%) + R290 (20%) are used. The purpose of alternative refrigerants has the advantage of being locally available and environment friendly nature. An unmodified deep freezer was charged and tested with each of the five hydrocarbon mixtures that consist of Propane [R290] (pure 100%), Iso -butane [R600a] (pure 100%), R600a (50%) + R290 (50%), R600a (20%) + R290 (80%), R600a (80%) + R290 (20%). The parameters investigated are the evaporator capacity, the pressure ratio, Variation of evaporator temperature with Specific heat, Variation of evaporator temperature with Vapour density, Variation of Evaporator temperature with cop. The present work shows that the propane is most suitable alternative refrigerant to HFC's with best performance among all other hydrocarbon mixtures investigated. When propane was used the evaporator temperature reached -20^{o}C with COP of 3.43 at condenser temperature of 27^{o}C as compared to COP of 2.75 for the R600a (20%) + R290 (80%) refrigerant at the same temperature.

Key words: Hydrocarbon mixtures, Refrigerants, Deep freezer.

INTRODUCTION

A Domestic deep freezer works on the principle of vapors compression Refrigeration cycle. The imperative components of the cycles are the evaporator, the compressor, the condenser and the expansion valve. Whole cycle runs on these four parameters and major function of the compressor is to increase the pressure of the working fluid (i.e., Refrigerant) from evaporator pressure to condenser pressure. The Refrigerant R134a (tetrafluoroethane) have zero ozone depletion layer and high global warming, which is currently using in the daily life. Hydrocarbon refrigerant like R600a (iso-butane) and R290a (propane) both have

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zero ozone layer depletion and negotiable global warming. Therefore these two refrigerants are individually blended with each other for better COP (coefficient of performance) and eco-friendly refrigerants to protect the environment. Many theories are concentrating on the application of eco-friendly refrigerants for Refrigeration systems and air conditioners.

The hydrocarbon (HC) as refrigerant has several positive characteristics such as zero ozone depletion potential, very low global warming, non-toxicity, high miscibility with mineral oil, good compatibility with the materials usually employed in refrigerating system. M. A. Hammad, M. A. Alsaad[1], in this paper focused on using alternative refrigerants that included propane, butane, and isobutene to replace R-12.Graphs were plotted and compared and finally concluded that propane mixture has the highest COP values among all hydrocarbons tested. The 50% propane mixture is selected to be the most suitable alternative refrigerant to R-12 based on both COP and saturated curve match characteristics.

R. Saravanakumar, V. Selladurai[2], conducted energy analysis of a hydrocarbon refrigerant mixture of R290/R600a as an alternative to R134a on the performance of a domestic refrigerator, which is originally designed to work with R134a and found that the performance refrigerator using R290/ R600a mixture as a refrigerant has higher value than R134a. It is obvious that the refrigerant with lower COP will consume more energy, which will have great adverse effect on the environment.

Akintunde, M. A.[3], conducted experimental study of the performance of eco-friendly refrigerants mixtures. The mixtures include R134a and R600a (by 50-50% (RA1), 30-70% (RA2)) and R600a and R406 (50-50% (RB1), 70-30% (RB2)).These mixtures are used to replace the R-12 refrigerant and concluded that the COP of all mixtures are nearly constant, and higher than R-12, but the COP of RB1 for is higher than that of R12 until the quantity of charging reaches 950 g, and it dropped sharply after then. In between 600 g and 950 g, the relative COP stands at 106% and it falls to 97% when the quantity of the charge was increased to 1000 g and above.

Wongwises and Chimres[4] (2005) investigated with Halocarbon mixtures having of R290 and R600 at different ratios like (60/40) in a domestic freezer and it is used as the replacement of R134a. By conducting experimental methods he concluded that blend uses less energy consumption per day when compared to R134a due to their excellent and high thermodynamic properties.

Tashtoush et al.[5], in his paper worked on the performance analysis of HC/HFC refrigerant blends like R600a/R600/R134a at various quantities in R-12 refrigerator. C.S jwo, c.c. Ting[6], investigated upon the mixtures of hydrocarbon refrigerants, R290 and R600a with each 50% component ratio, in place of R134a refrigerant in home refrigerators. The result shows that the effect of refrigerant is improved by using halocarbon refrigerant. At last he concludes that total consumed energy is saved 4.4% and applied mass of refrigerant is reduced 40%.

R. Y. Mahajan and S. A. Borikar[7], concluded that the performance of HC-12a (mixture of R290/R600a of (60/40)% by wt.) in refrigerator was constantly better than R134a for all the operating conditions, and he proved that HC-12 can be used as replacement of R134A in domestic refrigerator. Moo-Yeon Lee, Dong –Yeon Lee[8], Yongchan kim, studied the performance characteristics of small-capacity directly cooled refrigerator was evaluated by using R290 and R600a with mass fraction (55/45) as an alternative to R134a.He concluded that the refrigerant charge was approximately 50% of the optimized R134a system and also the energy consumption of R134a is 12.3% higher than that of optimized R290/R600a.

This paper involves the study of properties of the refrigerant blends by using refproperties software version 7.1 and also experimental work for evaluating the performance parameters of deep freezer with two pure refrigerants and their blends in three different proportions. They are:

(i) Propane [R290] (pure 100%)

(ii) Iso -butane [R600a] (pure 100%)

(iii) R600a (50%) + R290 (50%)

(iv) R600a (20%) + R290 (80%)

(v) R600a (80%) + R290 (20%).

EXPERIMENTAL

The Deep Freezer used in the present work has a capacity of 16 lit and is designed to work with the traditional refrigerant R134a. The mass of the refrigerant charge is 350 grams.The compressor is used as reciprocating, hermetically sealed type. Thermistor wires were installed at various locations in the deep freezer to measure the wall temperatures at inlet and outlet of the component temperature. A digital thermistor with an accuracy of 0.18C was used. Three mixtures propane, iso-butane, R600a (50%) + R290 (50%), R600a (20%) +R290 (80%), R600a (80%) +R290 (20%) are filled in to the compressor with the help of pressure gauge manifold one after the other. Thermistors for both the inlet and outlet of the compressor, condenser, evaporator and one thermo couple for measuring the water temperature. These are used for the measuring of wall temperatures of a deep freezer and these are connected to the 12 port temperature indicator. The readings are noted down for every 5 min continuously for 3 hrs for all the three blends.

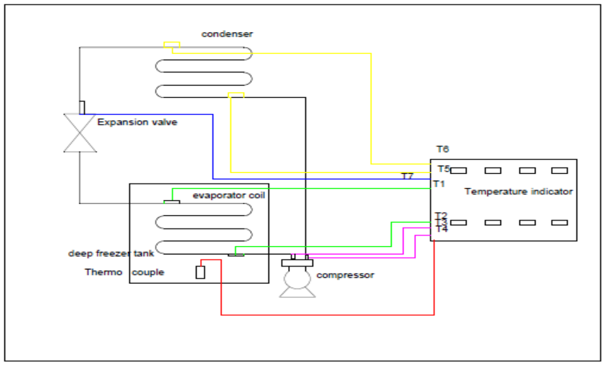

Fig. 1: Measuring locations of the test deep freezer setup

Procedure for making blends

To mix the two refrigerants the pressures of refrigerants at ambient temperature i.e., 30°C are considered. The one with low pressure is sent into the cylinder first and then the other refrigerants for proper mixture. The pressure of R290 and R600a is 4.047 bar and 7.7 bar respectively. An empty cylinder of volume 2 kg is taken and the cylinder is vacuumed with a vacuum pump so that the left over gas will be removed from the compressor. The weight of the empty cylinder is noted (1390 gms). To make R290 (80%) and R600a (20%) blend, firstly the total number of grams should be sent into the cylinder for each refrigerant is to be estimated.

Table 1: Thermodynamic properties of hydrocarbons

Refrigerant	Boiling point (°C)	Freezing point (°C)	Critical temp. (°C)	Critical pressure (Mpa)	Latent heat (KJ)	ODP	GWP
Propane (R290)	-29.3	-188	97	4.25	423.3	0	3
Isobutene (R600a)	-11.7	-160	135	3.65	364.4	0	3

For 1 Kg, 800 g of R290 and 200 g of R600a is taken. The empty cylinder is placed in a deep freezer for half an hour to maintain low pressures in the cylinder. The cylinder and

the refrigerant tin are connected using pressure manifold. Since, the pressure flows from high to low, once the valve is opened the refrigerant slowly enters into the cylinder. The weight of the cylinder should be monitored while the blending is taking place by using weighing machine. When the cylinder is filled with 200 g of R600a, the refrigerant is changed and the same process is followed till 800 gms of R290 refrigerant is filled. After the mixture is filled, the valve is tighted. The new mixture is charged into the compressor.

RESULTS AND DISCUSSION

The results of the evaporator temperature variation with respect to vapour density, specific heat, enthalpy, pressure ratio are studied in Figs. 1-4. As the propane percentage is increased in the hydrocarbon mixture, Qe is increased due to the increase of mass and the enthalpy difference across the evaporator. The variation of refrigeration effect with evaporation temperature is shown in Fig. 5. The propane COP is very high when compared to other refrigerants due to high latent heat of vaporization.

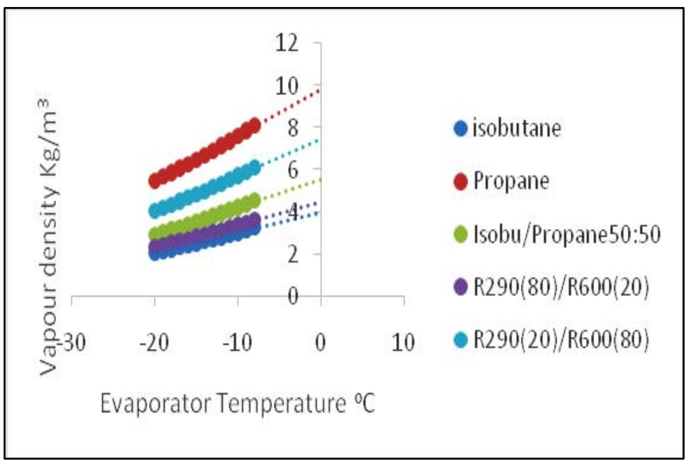

Fig. 1: Variation of evaporator temperature with Vapour density

In this graph shows the relation between evaporator temperature and the refrigerant vapour density. Pure propane vapour density value is higher than other refrigerants due to higher latent heat of vaporization. At evaporator temperature -20^{o}C the corresponding vapour density values are 2.0687 kg/m^3 for the isobutene, 5.5006 kg/m^3 for the propane , 2.9583 kg/m^3 for the mixture of 50:50 isobutene and propane, 2.3474 kg/m^3 for the mixture of 80:20 isobutene and propane, 4.05723474 kg/m^3 for the mixture of 20:80 isobutene and propane (Fig. 10).

The evaporator temperature at -20°C and the corresponding Specific heat value are 1.4989 kJ/Kg.K for the isobutane, 1.5801kJ/Kg.K for the propane, 1.522 kJ/Kg.K for the mixture of 50:50 isobutene and propane, 1.5067kJ/Kg.K for the mixture of 80:20 isobutene and propane, 1.5472kJ/Kg.K for the mixture of 20:80 isobutene and propane (Fig. 2).

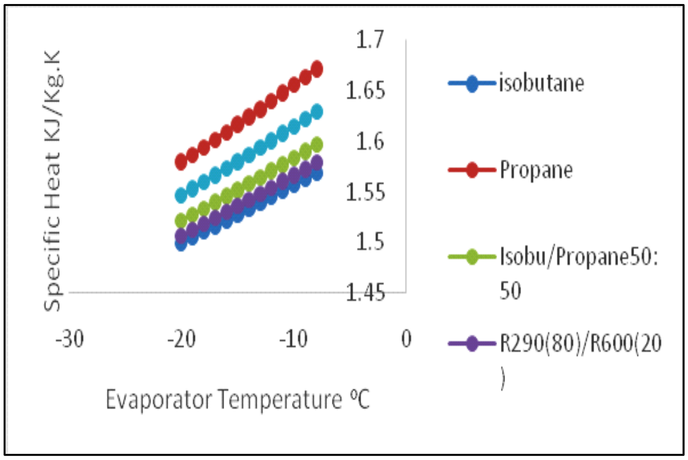

Fig. 2: Variation evaporator temperature with specific heat

At Evaporator temperature-20°C, Propane is having highest enthalpy value is (552.26 kj/kg) when compared to all other mixtures. This difference is occurs due to latent heat of vaporization of propane and its boiling point also very high (Fig. 3).

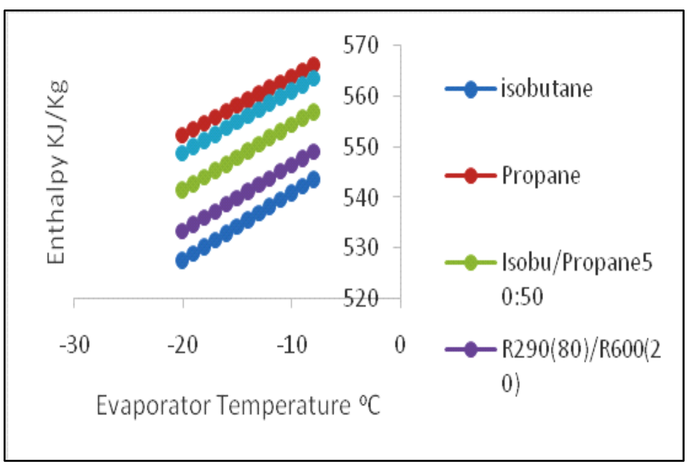

Fig. 3: Variation evaporator temperature with Enthalpy

At Condenser temperature 27°C for Propane is having highest enthalpy value is (603.15kJ/kg) when compared to all other mixtures. This difference is occurs due to refrigerant properties, latent heat of vaporization is more for propane and phase change occur very quickly compare to remaining refrigerant mixture (Fig. 4).

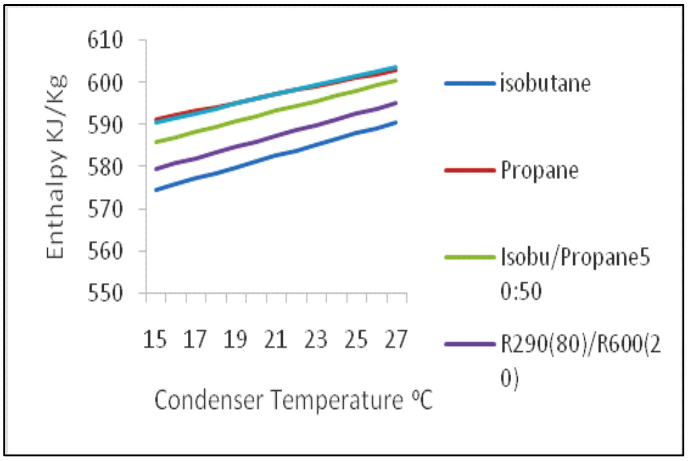

Fig. 4: Variation condenser temperature with Enthalpy

Evaporator temperature-20°C for Propane is having highest Latent heat of vapour enthalpy value is (552.26 kj/kg) when compared to all other mixtures. The refrigerant effect of evaporator temperature -8°C value is 59 watt. This difference is due to occurs refrigerant properties, and latent heat of vaporization is more for propane. So that phase change occurs very quickly (Fig 5).

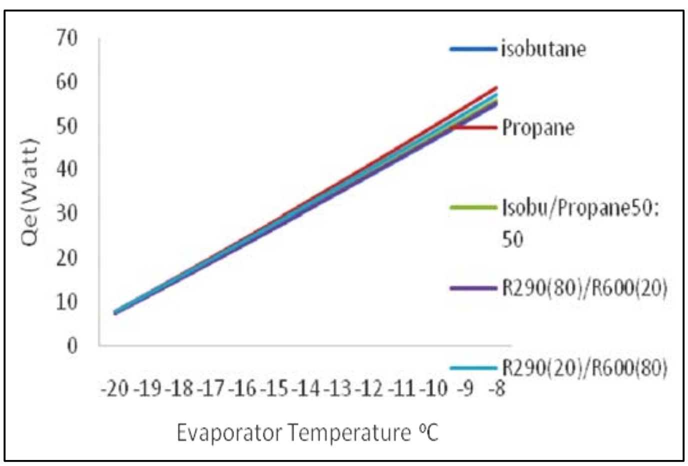

Fig. 5: Variation evaporator temperature with Qe

Evaporator temperature-20^{o}C for Propane is having very less pressure ratio. So the energy consumption also very less compare to other mixture and refrigerant. This is happening due to very high latent heat of vaporization. At Evaporator temperature -20^{o}C, Propane is having pressure ratio 2.99 bar (Fig. 6).

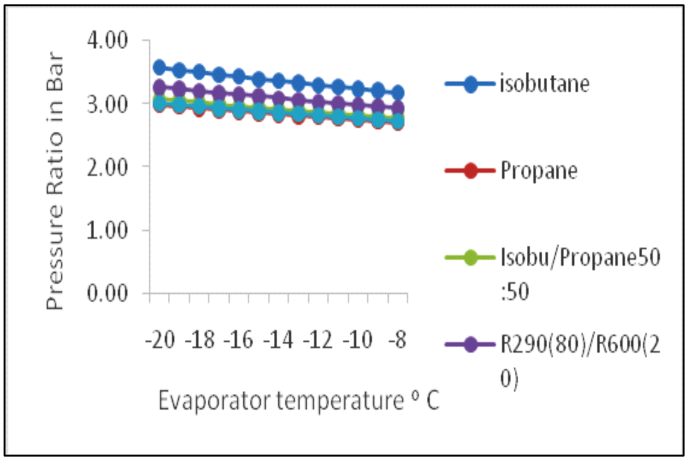

Fig. 6: Variation evaporator temperature with Pressure ratio

Evaporator temperature-20^{o}C for propane is having very high COP compare to other mixture and refrigerant .This is happening due to very high latent heat of vaporization. Evaporator temperature-20^{o}C for Propane is having COP 3.43 (Fig. 7).

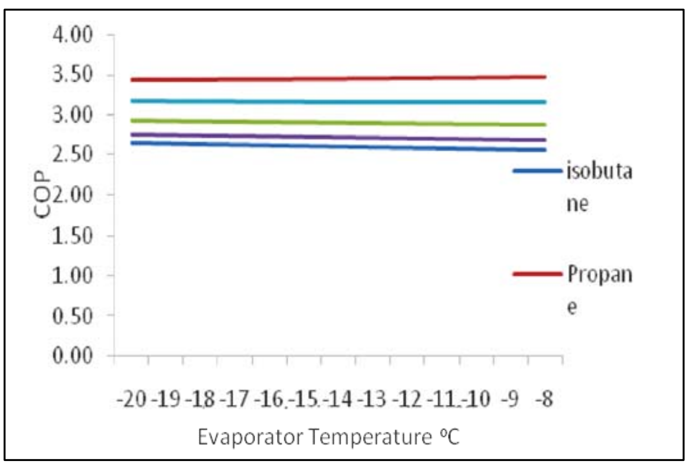

Fig. 7: Variation evaporator temperature with cop

CONCLUSION

The following conclusions are made are:

All investigated hydrocarbons and their mixtures of propane and iso-butane can be used as the alternatives to HFC's in the deep freezers designed for traditional R134a refrigerant. At -20°C of Evaporator temperature, Propane is having highest Latent heat of vapour enthalpy value (552.26 kj/kg) and enthalpy value is (552.26 kj/kg) it is due to very high latent heat of vaporization.

The refrigerant effect of evaporator temperature -8°C value is 59Watt and has high COP of 3.43 when compared to other refrigerant blends. The 100% propane gives better performance when compared to other refrigerants.

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