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# Performance Study of Geotropic Blends of Isobutane R600a and Propane R290 in Domestic Refrigerator as Alternative Refrigerants to R134a

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**ABSTRACT**

**The continuous increase in the cost and demand for energy has led to more research and development to utilize available energy resources efficiently. Vapour compression refrigeration method is an efficient method of refrigeration among the different methods, but the energy inputs to the Vapour compression system is high grade energy. This study focuses on an experimental study of hydrocarbon blend of isobutane (R-600a) and propane (R-290) as an environment friendly refrigerators with zero ozone depletion potential (ODP) and very low global warming potential (GWP), to replace conventional refrigerators tetrafluoroethane R-134a in a domestic refrigerators. The performance is observed for a domestic refrigerator by using blend of hydrocarbon R-600a and R-290 and its performance is compared with R-134a without change in original system. Due to the higher value of latent heat of hydrocarbons the amount of refrigerant charge required found to be reduced as compared with hydrofluorocarbon R-134a. Comparative performance study shows refrigerating effect is improved by using hydrocarbon blends, reduction of 40% in the refrigerant charge, the energy consumption per day reduced by 5%.**

***Keywords*— coefficient of performance COP, hydrocarbon, isobutane R600a, propane R290, R134a.**

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## I. INTRODUCTION

The most commonly used refrigerants in the early 1900s were natural refrigerants such as ammonia, carbon dioxide, sulphur dioxide and methyl chloride. All these refrigerants were found to be toxic or hazardous. In 1928, a safer class of alternative refrigerants became available with the invention of chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs). CFCs and HCFCs have many suitable properties such as stability, non–toxicity, non–flammable, good material compatibility and good thermodynamic properties, which led to their common wide spread use by both consumers and industries around the globe, especially as refrigerants in air–conditioning and refrigeration systems. Results from many researches show that ozone layer is being depleted due to the presence of chlorine in the stratosphere. The general consensus for the cause of this is that CFCs and HCFCs are large class of chlorine containing chemicals, which migrate to the stratosphere where they react with ozone. Later, chlorine atoms continue to convert more ozone to oxygen. The discovery of the depletion of the earth's ozone layer, which shields the earth's surface from UV radiation, has resulted in a series of international treaties demanding a gradual phase out of halogenated fluids. The CFCs have been banned in developed countries since 1996, and in 2030, producing and using of CFCs will be prohibited completely in the entire world. Also, the partially halogenated HCFCs are bound to be prohibited in the near future. The researches are going on to find out some alternate refrigerants which does not harm to the environment and the protective ozone layer. Research has shown that hydrocarbons are good alternative to existing refrigerants.

| Ref. | No. | Formula | ρl (kg/m3) | ρv (kg/m3) |
|---|---|---|---|---|
| Isobutane | R600a | CH–(CH3) 3 | 530 | 13.667 |
| Propane | R290 | CH3–CH2–CH3 | 467.07 | 30.202 |
| Propene | R1270 | CH2=CH–CH3 | 476.66 | 35.708 |
| R134a | R134a | CF3–CH2F | 1146.7 | 50.085 |
| R22 | R22 | CHClF2 | 1128.5 | 66.193 |
| Ammonia | R717 | NH3 | 579.44 | 12.034 |

## II. LITERATURE REVIEW

**Moo-Yeon Lee, Dong-Yeon Lee, Yongchan Kim[1]** In this study, the performance of a small-capacity directly cooled refrigerator was evaluated by using the mixture of R290 and R600a with mass fraction of 55:45 as an alternative to R134a. The compressor displacement volume of the alternative system with R290/R600a (55/45) was modified from that of the original system with R134a to match the refrigerationcapacity. Both systems with R290/R600a (55/45) and R134a were tested, and then optimized by varying the refrigerant charge and capillary tube length under experimental conditions for both the pull-down test and the power consumption test. The refrigerant charge of the optimized R290/R600a system was approximately 50% of that of the optimized R134a system.
The capillary tube lengths for each evaporator in the optimized R290/R600a system were 500mm longer than those in the optimized R134a system. The power consumption of the optimized R134a system was 12.3% higher than that of the optimized R290/R600a system. The cooling speed of the optimized R290/R600a (55/45) system at the in-case setting temperature of _15 _C was improved by 28.8% over that of the optimized R134a system.

**Gaurav , Raj Kumar [2]** This study presents a comparison of energy and exergy analysis for R134a, R152a, R290, R600 and R600a in refrigerator. The paper analyzes the domestic refrigerator with alternative refrigerants for computing coefficient of performance, exergy destruction ratio, exergy efficiency and efficiency defect. The method of exergy provides a measure to judge the magnitude of energy waste in relation to the energy supplied or transformed in the total plant and in the component being analyzed, a measure for the quality (or usefulness) of energy from the thermodynamic
viewpoint and a variable to define rational efficiencies for energy systems. It is established that in the present work
efficiency defect is maximum in condenser and lowest in evaporator. Comparison of various properties for alternative refrigerants has been done for a domestic refrigerator.

**Mohd. Aasim Nazeer Ahmad Quraishi, 1 U. S.Wankhede [3], this** paper presents a study of different environmental friendly refrigerants of either hydrocarbon or Hydro fluoro carbons (HFC) class. Hydrocarbons (HCs) have zero ODP and very low GWP whereas HFCs have zero ODP but a quite higher GWP. Almost in all the cases, when R-134a was replaced with HCs the COP of the system was improved, ON time ratio and energy consumption was reduced. Due to a higher value of latent heat of HCs, the amount of refrigerant charge was also reduced as compared with HFC-134a. When hydro chlorofluorocarbons (HCFCs) were replaced with HFCs the system delivered a poor performance with increased energy consumption. When nano particles were added to the refrigerant, system delivered better performance with reduced energy consumption than that of pure refrigerant.

**Rajanikant Y. Mahajan 1, Sanjaykumar A. Borikar [4],** this paper presents a study of different environment friendly refrigerants with zero ozone depletion potential (ODP) and negligible global warming potential (GWP), to replace R134a in domestic refrigerator. This work consists of using a hydrocarbon gas mixture which does not deplete ozone layer, is eco friendly, and can be used in the commonly used refrigerators without any significant change in the system. A refrigerator designed and developed to work with R134a was tested, and its performance using HC-12a was evaluated and compared with its performance when R134a was used. The condenser temperature and evaporator temperature, COP, refrigerating effect, condenser duty, work of compression and heat rejection of water were investigated. The energy consumption of the refrigerator during experiment with hydrocarbons and R-134a was measured. The results obtained showed that the alternative refrigerant investigated in experimental performance HC-12a have higher coefficient of performance and less energy consumption. The design temperature and pull-down time set by International Standard Organization (ISO) for small refrigerator were achieved earlier using refrigerant HC-12a than using R-134a. Due to a higher value of latent heat of HCs, the amount of refrigerant charge was also reduced as compared with HFC-134a. The COP and other result obtain in this experiment shows a positive indication of using mixed refrigerant as refrigerants in household refrigerator. The performance of HC-12a in the domestic refrigerator was constantly better than those of R134a throughout all the operating conditions, which shows that HC-12a can be used as replacement for R134a in domestic refrigerator. Refrigerant physical and chemical properties of different refrigerants are included in this paper. This paper also discuses on the C.O.P (coefficient of performance) and RE (Refrigeration Effect).

**Dr. A. G. Matani , Mukesh K. Agrawal [5],** there are a large number of refrigerants, which are used to transfer heat from low temperature reservoir to high temperature reservoir by using vapour compression refrigeration system. In this paper, experimental study was conducted to observe the performance of different environmental friendly refrigerant mixtures (HC mixture and R401a). It was also observed the effect of working parameters like diameter of capillary tube, working pressures and inlet water temperatures, which affect the coefficient of performance (COP) of vapour compression refrigeration system. It was observed that R134a is more efficient than HC mixture and R401a, but there is less mass quantity of HC mixture and R401a is required in the same system. So there is less effect in environment due to leakage.

 

**M. G. Almeida, C. R. F. Barbosa, and F. A. O. Fontes [6],** The research efforts and development in the refrigeration and air conditioning sector applied to the use of natural refrigeration fluids is not associated only with the need to preserve the environment alone, but has great importance with regard to the latent need for energy efficient equipment. With this perspective, the present study deals with the thermodynamic evaluation of the use of hydrocarbons refrigerants in household refrigeration systems that utilize HFC134a as a working fluid. A theoretical-computational analysis was developed for R134a, propane (R290) and the selected mixtures (R290/R600a 60%/40% R290/R600a/R134a 40%/30%/30% and R600a/R290 50%/50%) in the standard refrigeration cycle ASHRAE, using the thermodynamic and thermophysical properties provided by the REFPROP 6.0 software. The results of computational simulations between the fluids were compared to find the evidence of the best alternative to HFC134a. In this sense, it was observed that the hydrocarbons reduced the levels of pressure on the condenser and evaporator, along with smaller compression tasks necessary in the system, owing to the thermo-physical properties privileged in these fluids. The use of these fluids is also proportionate to lower temperatures of compressor discharge, increasing the life of this highly valuable component of the system.

**P.Thangavel, Dr.P.Somasundaram, T.Sivakumar, C.Selva Kumar, G.Vetriselvan [7],** In this analysis, the performance of compression cycle is assessed theoretically with different refrigerants. In compression refrigeration system, hydrocarbon refrigerants such as R290 and R600a are considered as a refrigerant by mixing of these at different mass fractions about 20%+80%, 25%+75%, 50%+50% and 75%+25% respectively. Various performance measures like compressor discharge temperature, pressure ratio, volumetric cooling capacity (VCC), volumetric efficiency and mass flow rate are analyzed. The results are compared with halogenated refrigerants such as R134a, R12 for different condenser and evaporator temperatures. Halogenated compounds are having direct environmental impacts in turns of ODP and GWP. Among the hydrocarbon refrigerants group, the mixture of R290 and R600a at concentration of 50% each has optimum performance in terms of higher refrigeration effect, better heat transfer and

## III. DESIGN AND DEVELOPMENT OF EXPERIMENTAL SET-UP

This section provides a description of the facilities developed for conducting experimental work on a domestic refrigerator. The technique of charging and evacuation of the system is also discussed here. The experimental setup of the test unit and apparatus is shown in the Figure.

Different experimental and theoretical comparison will performed to evaluate the performance of domestic refrigerator by using different refrigerants. In this experimental study of zeotropic blend of R600a and R290 (50/50)is compared with the R-134a in a domestic refrigeration system. To perform the experiment 40L refrigerator is selected which was designed to work with R-134a. It is consists of an evaporator, air cooled condenser, expansion device and reciprocating compressor. The refrigerator was instrumented with two pressure gauges at inlet and outlet of the compressor. The temperature at six different points is taken by six temperature sensors are mounted to measure the compressor inlet temperature, compressor delivery temperature, evaporator inlet temperature, evaporator outlet temperature, the freezer temperature and cabinet temperature. An ammeter is mounted at the inlet of the compressor to measure the power supply and voltmeter is also used for voltage of supply. Firstly cleaning is done with the help of nitrogen gas then evacuation is carried out with the help of vacuum pump and refrigerant is charged with the help of charging system. The refrigerant charge requirement with hydrocarbons is very small due to their higher latent heat of vaporization. As per the refrigerator manufactures recommendation quantity of charge requirement for HFC134a was 500 g. In the experiment, refrigerant charge is 10% higher due to the presence of instruments and connecting lines etc. To optimize the zeotropic blend of R600a and R290 (50/50) refrigerant charge, the refrigerator is charged with 170g and the performance was studied. The experimental procedures were repeated and take the reading for different mixtures from the various modes.

Fig. 1: Experimental Set-up

**Specification** for Experimental Set-up:

Water cooler –CAJ34G (KCJ444HAG)
Capacity (litres/hour): 40
Condenser size: 3/8'' O.D. 10-12 FPI -11''× 10''× 3''Row
Condenser fan motor: 1/36 H.P. × 1350 RPM
Condenser fan: 10'' Diameter
Evaporator tube: Size × Length 3/8'' O.D.×50''
Capillary: Bore × Length0.050'' ×5'× 1 number
HFC-134a commercial back pressure compressor
Cooling capacity: 1720 Btu/hr 433 kcal/hr
Rated Power and Current: 330 W and 2.34 A
Displacement: 12.58 cc/rev
Cooling type fan: 350 CFM
Oil charge quantity: 890 cc
Temperature range:-50 to + 80 °C
Humidity range for temp. Sensor :5% to 80%
Accuracy: ± .1 °C
Distinguish: 0. 1 °C
Power :two button battery (LR44, 1.5v)

B. Test Methodology:

 

Heat flows naturally from a hot to a colder body. In refrigeration system the opposite must occur i.e. heat flows from a cold to a hotter body. This is achieved by using a substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature sources. This is a basis of vapour compression cycle.

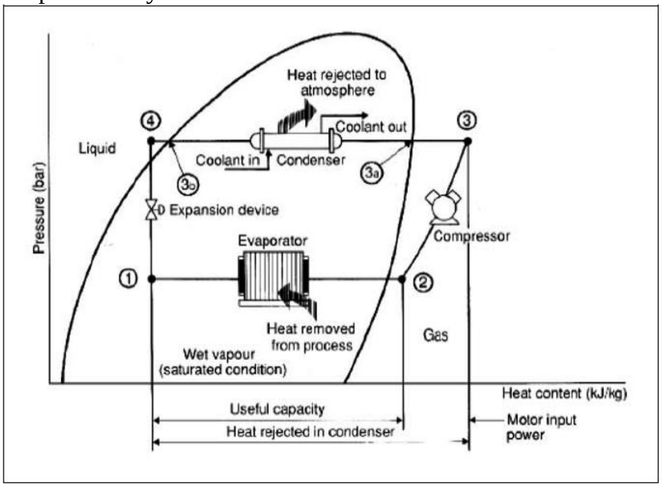


Fig. 2 Vapour compression refrigeration system

1 – 2: Low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas, and at the evaporator exit is slightly superheated.

2 – 3: The superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy input into the compression process is transferred to the refrigerant.

3 – 4: The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3 - 3a) desuperheats the gas before it is then turned back into liquid (3a - 3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b - 4), so that the refrigerant liquid is sub-cooled as it enters the expansion device.

4 – 1: The high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator

Tests were conducted on experimental set up for R134a to find out different parameters as discussed with suitable formula.

First all the components are arranged in technical manner and POE oil is filled in compressor .

The system leakage is checked by applying pressure and soapy bubbles.

The vacuum is created by using pump to maintain that negative pressure in the system pressure.

Then R134a is charged in system of 500 g and allow to run system.

Then all suction and discharge pressures were note down. Pcond and Pevap.

Temperature sensors are located at respective 8 locations to measure exact temperature at that point.

Then zeotropic blend of R600a and R290 (50/50) called as care 30 is used under study for same set up 170 g of care 30 is charged in system. And same procedure is repeated for readings.

C. Formulae Used:

1. The pressure ratio (PR) is defined as the ratio between the condensation pressure (Pcond) and evaporation pressure (Pevap):

$$\text{Pressure ratio PR} = \frac{P\ cond}{p\ evap} \quad (1)$$

2. The condensation and evaporation pressures are determined according to the condensation and evaporation temperatures, respectively.

The coefficient of performance (COP) relates the cooling capacity and power required and indicates the overall power consumption for a desired load. High COP means low energy consumption for absorption of the same cooling capacity of space to be refrigerated. Can be expressed as

$$COP=\frac{Qevap}{Pcomp} \quad (2)$$

where Qevap is the cooling capacity and Pcomp is power required to drive compressor.

3. Isentropic work of compressor (Wcomp) is expressed as :

$$W\ comp = (h2-h1) \quad (3)$$

4. refrigeration effect RE in other words the heat transfer rate of the evaporator (Qevap) is calculated as:

$$RE=Qevap=(h1-h4) \quad (4)$$

5. Power per ton of refrigeration is calculated as:

$$P/TR = \frac{3.5\ Wcomp}{RE} \quad (5)$$

## IV. RESULTS AND DISCUSSION

Experiments were carried out to investigate the thermal performance of refrigerator system and variations of temperature for each component with respect to time.

By using R134a refrigerants and zeotropic blends of R600a and R290 (50/50) is studied with different parameter at different load conditions.

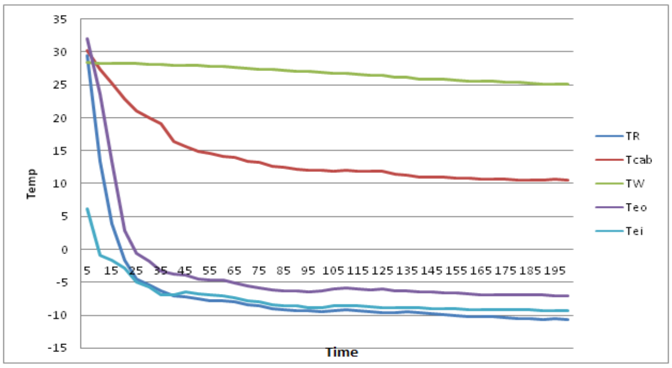


Fig. Time Vs TR, Tw, Tcab, Tei, Teo at 40 lit condition graph for R134a

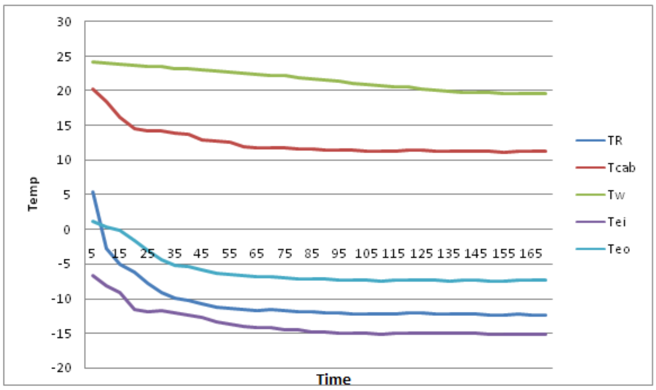


Fig.Time Vs TR, Tw, Tcab, Tei, Teo at 40 lit condition graph for zeotropic blend of R600a and R290 (50/50)

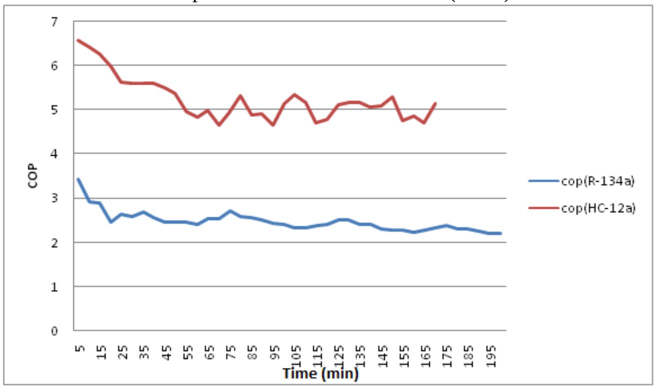


Fig.COP comparision for R134a and Zeotropic blend of R600a and R290(50/50)

## V. CONCLUSION

An experimental study has been carried out to investigate the thermal performance of refrigerator system with different refrigerants and its comparative study.

1. The thermal performance of R134a refrigerants and zeotropic blends of R600a and R290 (50/50) is studied at full load 40lit load conditions and comparison found that evaporator always shows lower temperature for R600a and R290 blend at all conditions.

2. Experimental results also revealed that the mass of R600a and R290 (50/50) had crucial effects on thermal performance. Approx. We found there is 60 % charge reduction of R600a and R290 (50/50) because of higher latent heat of vaporization.

3. COP of R600a and R290 (50/50) is found to be increased at all conditions compared with R134a. At full load 40lit average COP increments is found to be 4.6

Hydrocarbons blends may replace R-134a without any system modifications and COP of the system is improved with reduced energy consumption. So our future intension is that increase the requirement of HC-as a refrigerant in all types of domestic refrigerators and air conditioning system in near future. Due to the zero ozone depletion potential (ODP) and negligible global warming potential (GWP), environments becomes a safe and sweets. In develop countries HC as a refrigerant use in car air conditioning as well as industrial air conditioning.

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