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Experimental study of alternative refrigerants to replace R134a in a domestic refrigerator

AE Kharat[1], Dr. DM Mate[2], SD Kathwate[3]
[1] Research Scholar, GH Raisoni College of Engineering, Savitribai Phule Pune University, Ahemednagar, Maharashtra, India
[2] Professor, J.S.P.M. College of Engineering, Savitribai Phule Pune University, Tathawade, Pune, Maharashtra, India
[3] Professor, GH Raisoni College of Engineering, Savitribai Phule Pune University, Ahemednagar, Maharashtra, India

Abstract
Recently, The Ozone Depleting Potential (ODP) and Global Warming potential (GWP) have become the most important criteria in the development of new refrigerants apart from the refrigerant CFCs and HCFCs, both of which have high ODP and GWP due to their contribution to ozone layer depletion and global warming. Results from researchers show that the ozone layer is being depleted due to the presence of chlorine in the stratosphere. The general consensus for the cause of this that CFCs and HCFCs are large class of chlorine containing chemicals, which migrate to react with ozone. This leads to the strict prohibition Of CFCs. The R134a was the first chlorine-free refrigerant discovered (Bolaji, 2010). R134a is used nowadays as the working fluid in domestic refrigerators. But it was found that the R134a increasing significantly to the world's greenhouse warming problem. This caused scientists to investigate more environmentally friendly refrigerants than HFC refrigerants for the protection of the environment such as hydrocarbon mixtures as working fluid in refrigeration and air-conditioning systems. The possibility of using hydrocarbon mixtures as working fluid to replace R134a in domestic refrigerators has been evaluated through the simulation analysis. This simulation concludes that the hydrocarbon refrigerants offer desirable environmental requirements i.e., zero ODP and approximately zero GWP. A hydrocarbon blend of difluoromethane (R32), propane (R290) and iso-butane (R600a) is recommended to avoid the stratospheric ozone depletion. The presence of R600a in the mixture is miscible with both mineral oil and synthetic lubricants.

Keywords: refrigerant, R134a, R600a, R32, COP, GWP, ODP

1. Introduction
1.1 History of Refrigerator System
Human being are looking for ways to keep their food fresh, and found out that the coldness satisfy it. Therefore the idea of refrigeration was born. For centuries people relay on ice and snow for the purpose of cooling things. Since the Roman Empire, slaves used terracotta pots fanning in water to cool down the food. That is the method of cooling by extracting heat. Until 1844, Jacob Perkins, an American inventor acquired the pattern of the first evaporative cooling refrigerator and a new chapter of refrigeration has begun. After the invention of the first refrigerator, people started to gain more and more interest in using mane-made machines rather than natural ice for cooling food. The early refrigerator models in the nineteenth century made the foundation of the more functional and more stylized refrigerators in the future. Many kinds of refrigerator exist in our society today, each with its own distinct function. But the refrigerator in our home is the most commonly seen and utilized. Many families equip with a refrigerator. No matter of its color size or layout. It serves primary function to keep our food fresh. This study discuss specifically on home refrigerator. Like the air conditioner, it is also consist of the following four basic components: 1.Evaporator2.Compressor 3.Condenser 4.Expansion device [7].

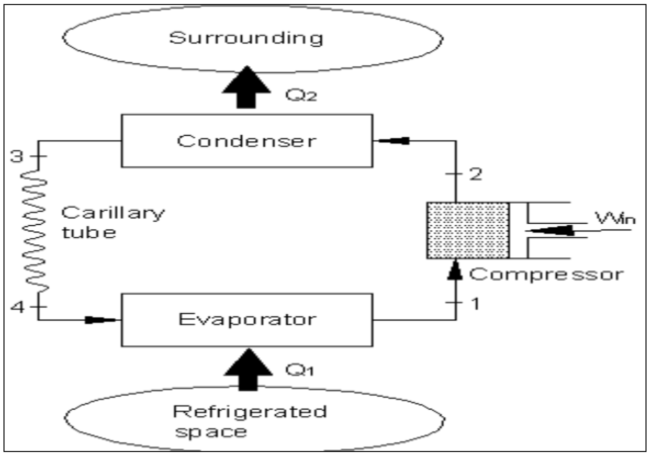


Fig 1: Schematic diagram of a refrigeration system

1.2 Introduction of Refrigerator System
Refrigerator is a cooling appliance comprising a thermally insulated compartment and a refrigeration system is a system to produce cooling effect in the insulated compartment. Meanwhile, refrigeration is define as a process of removing heat from a space or substance and transfers that heat to another space or substance. Nowadays, refrigerators are extensively used to store foods which deteriorate at ambient

temperatures; spoilage from bacterial growth and other processes is much slower in refrigerator that has low temperatures. In refrigeration process, the working fluid employed as the heat absorber or cooling agent is called refrigerant. The refrigerant absorbs heat by evaporating at low temperature and pressure and remove heat by condensing at a higher temperature and pressure. As the heat is removed from the refrigerated space, the area appears to become cooler. A vapor compression cycle is used in most household refrigerators, refrigerator–freezers and freezers. In this cycle, a circulating refrigerant such as R134a enters a compressor as low-pressure vapor at or slightly above the temperature of the refrigerator interior. The vapor is compressed and exits the compressor as high-pressure superheated vapor. The superheated vapor travels under pressure through coils or tubes comprising "the condenser", which are passively cooled by exposure to air in the room. The condenser cools the vapor, which liquefies. As the refrigerant leaves the condenser, it is still under pressure but is now only slightly above room temperature. This liquid refrigerant is forced through a metering or throttling device, also known as an expansion valve (essentially a pin-hole sized constriction in the tubing) to an area of much lower pressure. Thesudden decrease in pressure results in explosive-like flash evaporation of a portion (typically about half) of the liquid. The latent heat absorbed by this flash evaporation is drawn mostly from adjacent still-liquid refrigerant, a phenomenon known as "auto-refrigeration". This cold and partially vaporized refrigerant continues through the coils or tubes of the evaporator unit. A fan blows air from the refrigerator or freezer compartment ("box air") across these coils or tubes and the refrigerant completely vaporizes, drawing further latent heat from the box air. This cooled air is returned to the refrigerator or freezer compartment, and so keeps the box air cold. Note that the cool air in the refrigerator or freezer is still warmer than the refrigerant in the evaporator. Refrigerant leaves the evaporator, now fully vaporized and slightly heated, and returns to the compressor inlet to continue the cycle [1, 2, 3-10].

- Main Component of refrigerator
  1. Compressor
  2. Condenser
  3. Expansion (capillary)
  4. Evaporator

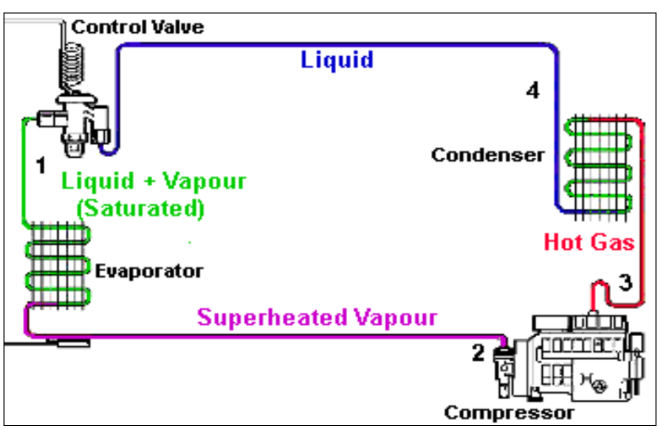


Fig 2: Schematic diagram of a refrigeration system

1.2.1 Main function of each component of refrigeration system

a) **Compressor:** The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve A, where it is compressed to a high pressure and temperature. This high pressure and temperature vapour refrigerant is discharged into the condenser through the delivery or discharge valve B.

b) **Condenser:** The condenser or cooler consists of coils of pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.

c) **Receiver:** The condensed liquid refrigerant from the condenser is stored in a vessel known as receiver from where it is supplied to the evaporator through the expansion valve or refrigerant control valve**.** It is used for the constant supply of refrigerant to the evaporator.

d) **Expansion Valve:** It is also called throttle valve or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator at the low pressure and temperature.

e) **Evaporator:** An evaporator consists of coils of pipe in which the liquid-vapour. Refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

a. Front view b. Back side view

Fig 3: Actual diagram of a refrigeration system

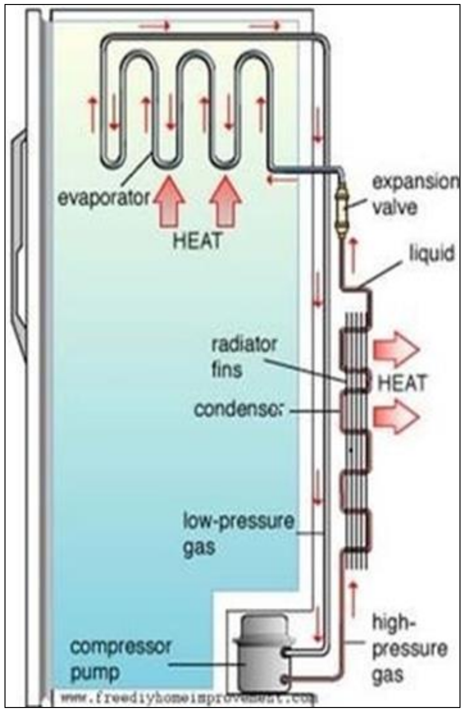


Fig 4: Actual working diagram of a refrigeration system

1.2.2 Processes Involved in Vapor Compression Refrigeration Systeme

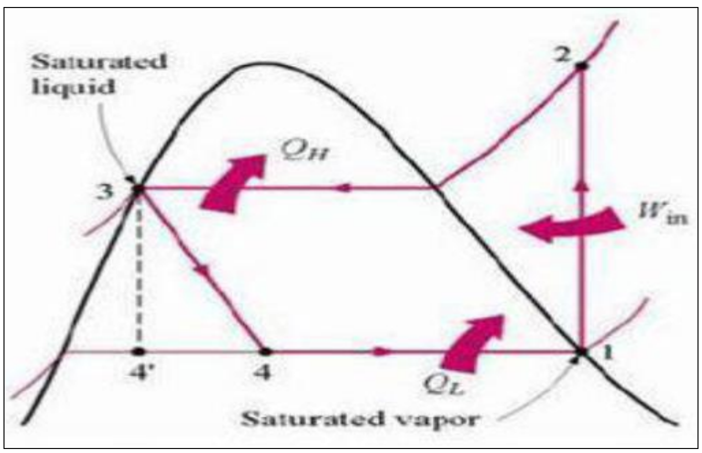


Fig 5: T-S Diagram for the Ideal Vapor Compression Refrigeration Cycle

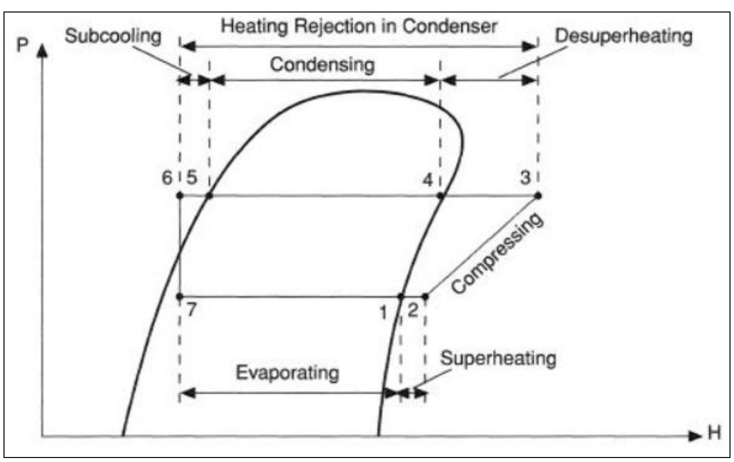


Fig 6: Pressure-enthalpy graph for vapour compression refrigeration system

Process 1 – 2: Isentropic compression in compressor.
Process 2 –3: Constant pressure heat rejection in condenser.
Process 3 – 4: Isenthalpic expansion in expansion device.
Process 4 –1: Constant pressure heat absorption in evaporator.

1.2.3 Advantages of Vapour Compression Cycle

1. C.O.P. is quite high as the working of the cycle is very near to that of reversed Carnot cycle.
2. When used on ground level the running cost of vapour compression refrigeration system is only 1/5 of air refrigeration system..i.e. it has low running cost.
3. For the same refrigeration effect the size of the plant is smaller.
4. The required temperature of the evaporator can be achieved simply by adjusting the control valve of the same unit.

1.2.4 Factors Affcting the Performance of VC Refrigration System

From the literature survey it is observed that following factors affect the performance of vapour compression refrigeration system.

1. Properties of working fluid.
2. Mixture proportions of different refrigerants.
3. Suction pressure.
4. Discharge pressure.
5. Pressure ratio.
6. Amount of charge filled.
7. Dimensions of capillary tubes

1.3 Refrigerant

1.3.1 What Is Refrigerant

The working fluid used to transfer the heat from low temperature reservoir to high temperature reservoir is called refrigerant.

1.3.2 Different Types of Refrigerant

1. **Halocarbon compound**: They are molecules composed of carbon, chlorine and fluorine. They are stable, allowing them to reach the stratosphere without too many problems. It contributes to the destruction of the ozone layer. Some important halocarbon are: R11, R12, R13, R21, R22, R40, R100, R113, R114, R152
2. **Azeotropes:** This group of refrigerant consists of mixture of different refrigerant which cannot be separated under pressure and temperature and they have fixed thermodynamic properties.e.g.R500 is the mixture 7308% of R1226.2% of R152.
3. **Hydrocarbons (HC):** This is primarily propane (R290), butane (R600) and isobutene (R600a). These fluids have good thermodynamic properties, but are dangerous because of their flammability. The world of the cold has always been wary of these fluids, even if they have reappeared recently in refrigerators and insulating foams. Their future use in air conditioning seems unlikely, given the cost of setting both mechanical and electrical safety.
4. **Inorganic compounds:** Before the development of hydrocarbon group refrigerants, these were used in past commonly used refrigerants of his group are:R717-Ammonia(NH3),R718-Wter(H2O),R729-Air,R744,(CO2),R764-Sulphur dioxide(SO2)
5. **Unsaturated organic compounds:** This group of refrigerants is hydrocarbon with ethylene and propylene base. Example is: R1120-Trichloroehylene (C2HCL3), R1130 Dichlroehylene (C2H2CL2), R1150-Ethylene (C2H4), R1270-Propylene (C3H6), R1270-Propylene (C3H6) [10, 12].

1.3.3 Properties of good refrigerant

1. Low boiling point and high latent heat of vaporization
2. Non-flammable
3. Low toxicity
4. Low miscibility with oil
5. Low cost
6. Good heat transfer rate
7. Low freezing point
8. Low power consumption
9. High efficiency
10. Negligible ODP,GWP

The main objective in this study to development of Hydrocarbon blends "to study alternative refrigerants to replace R134a in a domestic refrigerator" and calculated EER, COP GWP, ODP in different methods like that practical, theoretical, software. The main function of this statistical models or use is Performance Evaluation of Domestic Refrigerator Using new eco- friendly Refrigerant as an Alternative with commonly used Refrigerant like that R32, R600a, R290, R12 And R134a.because of following reasons In India, about 80% of the domestic refrigerators use R134a as refrigerant due to its excellent thermodynamic and thermo physical properties. But R134a has high GWP of 1300. The higher GWP due to R134a emissions from domestic refrigerators Leads to identifying a long term alternative to meet the requirements of system performance, refrigerant-lubricant interaction, energy efficiency, environmental impacts, safety and service. The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) calls for reductions in emissions of six categories of greenhouse gases, including hydro fluorocarbons (HFCs) used as refrigerants. From the environmental, ecological and health point of view, it is urgent to find some better substitute for HFC refrigerants. Many investigators have reported that GWP of HFC refrigerants is more significant even though it has less than that of chlorofluorocarbons (CFC) refrigerants. Refrigerators are identified as major energy consuming domestic appliance in household environment. Many researchers have reported that hydrocarbon mixed refrigerants is found to be an energy efficient and environment friendly alternative option in domestic refrigerators. The literature review brings out the fact that many researchers have studied with different hydrocarbon refrigerant mixtures as alternative to R12 and R134a in domestic refrigerators. However, the possibility of using HCM (composed of 45.2% of R290 and 54.8% of R600a) as R134a alternative at different ambient temperatures needs further in visitation. The objective of the present study is to explore the possibility of using above mentioned HCM in a 150 l domestic refrigerator with different mass charges (40, 50, 60 and 70 g). The influence of ambient temperatures on the performance characteristics of the refrigerator under continuous and cycling running operating mode at different freezer air temperatures with 32 ◦C ambient temperature have been studied [1, 2-12].

Refrigerant Selection

In refrigeration and air conditioning systems selection of an appropriate working fluid is one of the most significant steps for a particular application. Low global warming potential has been inserted to the long list of desirable criteria of refrigerant's selection. In fact, environmental characteristics of refrigerants are becoming the dominant criteria provided that their thermodynamic behaviors and safeties are favorable as well.

1. Environmental impact and safety aspects
2. Zero ODP and Low GWP Refrigerant

2. Literature Review

In recent past, R134a, R12 was used as working substance in domestic refrigerator. But use of R12 was abandoned because of ozone layer depletion (ODP) problem. Or use of R12 was abandoned because of Global Warming Potential (GWP) problem now a day, R600a is used as working substance in domestic refrigerator. R600a (Hydrocarbon refrigerant) is used in domestic refrigeration and other vapor compression system.

K. Mani *et al* [1] experiments are conducted using R12, R134a and R290/R600 mixture refrigerants. In this work the following conclusions are made. A five level factorial experimentation technique is employed for developing statistical models and the performance of R12, R134a and R290/R600 (79/21 by wt %) mixture are compared. The refrigerating capacity of R290/R600 (79/21 by wt %) is 49% higher for lower Te temperatures and 30% higher for higher Te than that with R12 and R134a R290/R600 mixture consumed 21.3%-22.2% higher power than R12 and R134a at all the operating conditions due to the increased work of compression.

Mahmood Mastani Joybari *et al*. [2] studied first energy analysis was carried out for 145 g of R134a. Then, R134a was replaced by 60 g of R600a, compressor was changed to a HC type one and energy analysis was applied to the refrigerator to improve its performance. According to the results, R600a charge amount, compressor COP and condenser fan rotational velocity were selected for Taguchi design. It was found that at optimum condition the amount of charge required for R600a was 50 g which is 66% lower than R134a one; Besides, R134a is about two times more expensive than R600a which makes R600a use economically beneficial. Compressor modification is strongly recommended to enhance the system. Furthermore, the amount of total energy destruction in optimum condition (0.025 kW) is 45.05% of the base refrigerator one (0.05549 kW) which confirms the enhancement of the cycle for 54.95%.

Mujahid sheikh *et al*. [3]. Studied Energy Efficiency Ratio of R-600a is higher than R-134a. Experiment carried out using refrigerant R134a and R600a at in Domestic Refrigerator; it is found that cooling Capacity using Refrigerant for constant refrigeration effect is 107.03. Whereas for same refrigeration effect the cooling Capacity using Refrigerant R600a is 142.10. Compressor energy consumption of domestic refrigerator decreased by 10-15% with using refrigerant R600a.

Rajanikant Y. Mahajan *et al*. [4]. studiedhe harmful refrigerants are to be phased out and are to be replaced with alternate environmental friendly refrigerants with zero ozone depletion potential (ODP) and negligible global warming potential (GWP), to replace R-12 and R134a in domestic refrigerator Hydrocarbons blends may replace R-134a without any system modifications. COP of the system is improved with reduced energy consumption. Hydrocarbon refrigerants are compatible with mineral oils (commonly used lubricants). Hydrocarbon technology provides a simple, sustainable and cost-effective solution for replacing R-134a in the domestic refrigeration subsector in developing countries.

Raj Kumar *et al*. [5] R600 has the highest value of EER among R134a, R152a, R290, R600 and R600a at 40°C but at 55°C R600a has the highest value of EDR among R134a, R152a, R290, R600 and R600a.R600a has the highest value of Efficiency defect in compressor among R134a, R152a, R290, R600 and R600a.R290 has the highest value of Efficiency defect in throttle valve among R134a, R152a, R290, R600 and R600a.R600 has the highest value of Efficiency defect in evaporator among R134a, R152a, R290, R600 and R600a.

Vandana Jatav *et al*. [6]. The COP of the system has been improved with the hydrocarbon refrigerants. The average COP of HC 19% higher than that of R134a.The domestic refrigerator was charged with 60g in 134a and 40g of HC. This is indication of better performance of HC as refrigerants. Refrigeration efficiency of the system increases with the increases in condensing and evaporating temperature. Mass flow rate is reduced when we are using hydrocarbon as refrigerant.

Ajoy Bhargav *et al*. [7] comparison of mint gas is done with R-12 and R-134 for in domestic refrigerators. From the observation we found that mint gas can be an option which could produce better results. Al though its implementation requires a detail experimental calculations. Mint gas is providing more COP then ordinary refrigerants another advantage of this refrigerant was that it does not react with compressor oil. The only disadvantage associated with this gas is its flammability, which can be an obstacle in its implementation. This problem can be solved by proper design of the refrigerator.

R. Cabello *et al*. [8] studied the influence of the evaporating pressure, condensing pressure and superheating degree of the vapour on the exergetic performance of a refrigeration plant using three different working fluids R134a, R407c, R22.

K. Senthil Kumar *et al*. [9]. Studied the behavior of HCFC (Hydro chloro fluro carbon) -123/ HC-290 refrigerant mixture computationally as well as experimentally and found that refrigerant mixture 7/3 as a promising alternative to R12 system.

B.O. Bolaji *et al*. [10]. Investi gated experimentally the performances of three ozone friendly Hydro fluorocarbon (HFC) refrigerants R12, R152a and R134a. R152a refrigerant found as a drop in replacement for R134a in vapour compression system.

B.O. Bolaji [11] discussed the process of selecting environmental-friendly refrigerants that have zero ozone depletion potential and low global warming potential. R23 and R32 from methane derivatives and R152a, R143a, R134a and R125 from ethane derivatives are the emerging refrigerants that are non toxic, have low flammability and environmental-friendly. These refrigerants need theoretical and experimental analysis to investigate their performance in the system.

A.S. Dalkilic *et al*. [12]. studied the performance analysis of alternative new refrigerant mixtures as substitute for R12, R134a and R 22. Refrigerant blend of R290/R 600a (40/60 by wt. %) and R 290/R1270 (20/80 by wt. %) are found to be the most suitable alternative among refrigerants tested for R12 and R22.

S. Wong wises *et al*. [13] found that 6/4 mixture of R290 and R600 is the most appropriate refrigerant to replace HFC134a in a domestic refrigerator.

K Mani *et al*. [14] found that R290/R600a (68/32 by wt. %) can be considered as a

Drop in replacement for R12 and R134a.

Bukola O. Balaji *et al*. [15] investigated the exergetic performance of R12 and its substitute (R134a and R 152a) in the domestic refrigerator. R152a performed better than R134a in terms of COP, exergetic efficiency and efficiency defect as R12 substitute in domestic refrigeration system.

Alka Bani Agrawal *et al*. [16]. Worked on eco-friendly refrigerant as a substitute for CFC (Chloroflurocarbon). The binary mixture in the ration of 64% and 36% of R290 and R600a found to be a retrofit or drop in substitute of R12 for use in the vapour compression refrigeration trainer.

Akhilesh Arora *et al*. [17] had worked on a detailed analysis of an actual vapour compression refrigeration cycle. A computational model had been developed for computing coefficient of performance, exergy destruction, exergetic efficiency and efficiency defects for R502, R404A and R507A. The investigation had been done for evaporator and condenser temperatures in the range of -50°C to 0°C and 40°C to 55°C respectively. The results indicate that R507A was a better substitute to R502 than R404A.

Miguel Padilla *et al*. [18]. found that R413A (mixture of 88% R134a, 9%R218, 3%R600a) can replace R12 and R134a in domestic refrigerator

Mohan M. Tayde, and *et al*. [19] design and investigated with classical refrigeration using vapour compression has been widely applied over the last decades to large scale industrial systems. Now, the mini-scale (miniature) refrigerator using VCR seems to be an alternative solution for the electronic cooling problem. Fabrication of very small devices is now possible due to advances in technology. In this investigation a mini-scale refrigerator of 300W cooling capacity using R-134a as refrigerant is designed, built and tested. This test indicates that the actual COP of the developed system is 1.6 and second law efficiency is 19%.

Somchar Wongwiises and *et al*. [20] conducted an experimental study on the application of hydrocarbon mixtures to replace HFC- 134a in a domestic refrigerator. The hydrocarbons investigated are propane (R290), butane (R600) and isobutene (R600a). The consumed energy, compressor power and refrigerant temperature and pressure at the inlet and outlet of the compressor are recorded and analyzed as well as the distributions of temperature at various positions in the refrigerator. The experiments are conducted with the refrigerants under the same no load condition at a surrounding temperature of 25 oC. The results show that propane/butane 60% - 40% is the most appropriate alternative refrigerant to HFC-134a.

M. A. Sattar, and *et al*. [21] studied the domestic refrigerator designed to work with R-134a was used as a test unit to assess the possibility of using hydrocarbons and their blends as refrigerants. Pure butane, isobutene and mixture of propane, butane and isobutene were used as refrigerants. The performance of the refrigerator using hydrocarbons as refrigerants was investigated and compared with the performance of refrigerator when R-134a was used as refrigerant. The effect of condenser temperature and evaporator temperature on COP, refrigerating effect, condenser duty, work of compression and heat rejection ratio were investigated. The energy consumption of the refrigerator during experiment with hydrocarbons and R-134a was measured. The results show that the compressor consumed 3% and 2% less energy than that of HFC-134a at 28 °C ambient temperature when iso-butane and butane was used as refrigerants respectively. The energy consumption and COP of hydrocarbons and their blends shows that hydrocarbon can be used as refrigerant in the domestic refrigerator. The COP and other result obtained in this experiment show a positive indication of using HC as refrigerants in domestic refrigerator.

A. Baskaran1, and *et al*. [22] determined the performance analysis on a vapour compression refrigeration system with various eco-friendly refrigerants of HFC152a, HFC32, HC290, HC1270, HC600a and RE170 were done and their results were compared with R134a as possible alternative replacement. The results showed that the alternative refrigerants investigated in the analysis RE170, R152a and R600a have a slightly higher performance coefficient (COP) than R134a for the condensation temperature of 50 C and evaporating temperatures ranging between -30 C and 10 C.

Refrigerant RE170 instead of R134a was found to be a replacement refrigerant among other alternatives. The effects of the main parameters of performance analysis such as refrigerant type, degree of sub cooling and super heating on the refrigerating effect, coefficient of performance and volumetric refrigeration capacity were also investigated for various evaporating temperatures.

Mohd. Aasim, and ***et al*.** [23] investigated experimental study of isobutene (R-600a), an environment friendly refrigerants with zero ozone depletion potential (ODP) and very low global warming potential (GWP), to replace R-134a in domestic refrigerators. A refrigerator designed to work with R-134a was tested, and its performance using R-600a was evaluated and compared its performance with R-134a. The average COP using R-600a was 27% higher than R-134a respectively. The power consumption by compressor reduced by 3.7% with R600a refrigerant. The compressor ON time ratio was lowered by 6.98% with R-600a compared with R- 134a. The experimental results showed that R-600a can be used as replacement for R-134a in domestic refrigerator.

Balakrishanan. p and *et al*. [24] explores an experimental investigation of an ecofriendly refrigerant for R134a with better cop, reduced GWP and ODP. Has taken hydrocarbon mixture R32/R600/R290 in the ratio of 70:5:25 by weight. he found that using hydrocarbon mixture of R32/R600/R290 at loading on condition time, The cop and mass flow rate values are higher than R134a.but its starting colling process is lower than R134a.so for that we should have to take different hydrocarbon mixture of R32/R600/R290 ratio by weight.

M. mohanraj and *et al*. [25] studied that the energy performance of a domestic refrigerator has been assessed theoretically with R134a and R430a as alternative refrigerant. and he concludes that R430a has a low gwp of 109 as compare to R134a.

J.K. Vaghela [26] is derived that R1234yf is best suitable is best suitable alternative refrigerant to R134a.he concludes that R1234yf has lower cop as compared to R134a;however it is best suitable refrigerant as drop in substitute because it has very low GWP and can be substituted in the existing automobile air conditioning system with minimum modification.

M. Rasti *et al***.** [27] studied that substitution of two hydrocarbon refrigerants instead of R134a in domestic refrigerator. Experiments are designed on a refrigerator manufactured for 105 g R134a charge. the effect of parameters including refrigerant type, charge and compressor type are investigated. His research is conducted using R436a and R600a as a hydrocarbon refrigerant.

2.1 Research Gap

By studying the all above literature research, They hve done various experiments by using different refrigerant like R12, R290, R600a, R436a, R430a, pure and blends of hydrocarbons etc.by studying all these parameters I am going to study with different hydrocarbon blends of R32,R600a,R290.also by using R1234yf which is joint venture of Dupont and Honeywell in domestic refrigerator without any modification in VCR system.

3. Problem Statement

Recently, The ODP And GWP Have Become Most Important Criteria in The Development Of New Refrigerants Apart From The Refrigerant CFC's and HCFC's, both of which have high ODP and GWP.

In the present work, the problem of R134a is Identified from environmental site that R134a having a high GWP and due to this alternative refrigerants is chosen with better mixing ratio. Thereby, the Cop of the alternate refrigerant and R134a are compared, hence the main objective is to select an alternate Refrigerant with an increased cop and reduced GWP and ODP.

3.1 Objective of Project

The development of statistical models, new hydrocarbon blends, to investigate COP, GWP, ODP, EER of domestic refrigerator in different methods like that practical, theoretical, software.& Electric Power Consumption, Refrigeration Capacity, Compressor work and Coefficient of Performance (COP) by determining important parameters during in operating mode which are temperature, pressure with domestic refrigerator using Refrigerant R134a, R1234yf, Blends of R32, R600a, R290 at Constant Evaporator Temperature.

1. TO Find Out GWP And ODP.
2. To find out COP.
3. To become aware about how to calculate EER and to give energy star rating of domestic refrigerator
4. Analysis of simple vapor compression cycle with the help of suitable refrigeration software like Gene tron (V1-2), cool pack, the rmof low and find out
   a) COP
   b) T-S & P-H dia of given cycle

4. Methodology

The first step is to study the alternative refrigerant to replace R134a in a domestic refrigerator. The details of the experiment setup is shown in Table-1

Table 1: Details of Experimental Set-up

Si no	Description	Dimension/Range
1	Refrigerator Capacity	200 litres
2	Capillary Tube	0.031mm
3	Compound Gauge	-30-220psi
4	Pressure guage	0-300 psi
5	Vaccum Pump	-30PSIG
6	R32/R600a/R290	100gm

The R134a domestic refrigerator setup consist of a hermatically sealed compressor, natural convection air cooled condenser having a cooling capacity level of 5.67KW/hr, an evaporator and copper capillary tube whose schematic diagram and photographic view of the experimental set up is given in the fig 1 and fig 2.Sensor is attached at the inlet and outlet of compressor, condenser and evaporator. Pressure gauge is attached at the compressor inlet and outlet. Compound gauge is fitted at the condenser outlet. Evacuation of moisture takes place with the help of service port service port. Vaccum pump is used for evacuation and through the charging system refrigerant was filled in the refrigeration system. Properties of R32/R600a/R290 refrigerant from ASHRAE handbook are given in the Table 2.

Table 2: Properties of R32/R600a/R290

Refrigerant	R32	R600a	R290
Safety level	A1	A1	A1
Boiling point(0C)	-52	-11	-41
Tcon(OC)	78.1	137.7	66
COP	2.11	1.99	2.01
ODP	0	0	0
GWP	71.5	-20	-20

Methodology of this work is concentrated on two important things that need to be developed in order to investigate the performance of the domestic refrigerator which is location of measurement points and it devices, and experiment set-up.

4.1 Development of Location of Measurement Points

Refrigerator test rig was developed in order to investigate the performance of the system. In developing the reliable refrigerator test rig, consideration should be highly addressed especially the development method and measurement locations of pressure and temperature. They discussed the locations of temperature and pressure measurement points, measurement devices and measurement methods. As a result, a refrigerator test rig was developed as shown in Fig.5.1.1. There are five points of temperature measurement, two points of pressure measurement and one is energy measurement [8].

From the five points of temperature measurement, four points have been placed inside the refrigeration circuit to measure refrigerant temperature and another one points have been placed in refrigerator compartments. The thermocouple wire was used to measure the temperature of refrigerant in the tube. The technique to measure the temperature is the same as Philipp *et al* (1996), where the thermocouple wire was put inside the refrigerant tube so that the measurement made was exactly the temperature of the refrigerant. However, the method to construct the sensor was different. Figure shows the method to construct the temperature measurement point in the refrigerant tube [8].

By using this method, as shown in Figure was used to hold a thermocouple wire which was inserted into the tube and effectively sealed, as shown in Figure. The flared tube is fitted securely on to a copper J-junction which was then joined mechanically to the tube to reconnect every two consecutive components. The temperature of the refrigerant which now flowed through each J-junction was measured by the hot thermocouple junction or head, as shown in Figure 7. Prior to installation each thermocouple was calibrated using a platinum thermocouple against temperature of freezing point, room condition and boiling point of water.The thermocouple used was of J-type, 0.3 mm diameter and designed for temperature range between -50°C to 99°C. The accuracy is about ±2%.

Fig 7 Actual Image Thermocouple Scanners and Wire

Fig 8: Fabrication of Assembly method of Thermocouple

Besides that, two points of pressure were tapped respectively made on pipes connecting all main components. Experimental works of Pannock J *et al*. (1994), Philipp, J *et al*. (1996), and Melo, C and Pereira, R. H (1988) only measured suction and discharge pressures of compressor while the present works allowed pressure drops across each component and along connecting pipes to be known (Jones, 2001, ASHRAE, 2001). Bourdon Tube pressure gauges were used for each pressure measurement in this test rig (ANSI/ASHRAE Standard, 1989, ARI 1998). A tube with diameter 2.1 mm was used to connect the refrigerant tube to each pressure gauge as what was done by Philipp. Figure 7 shows the detail construction of the pressure measurement points [8].

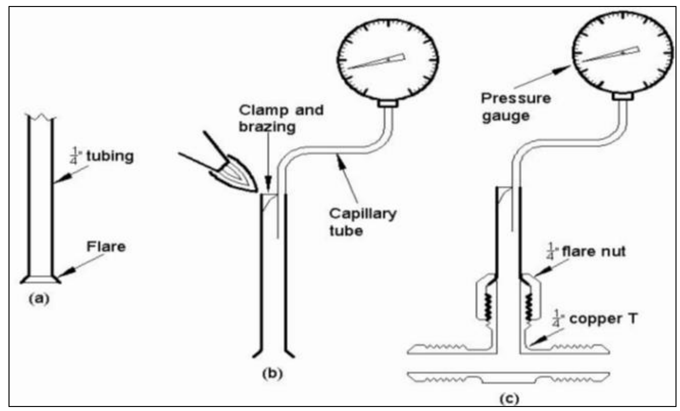


Fig 9: Assembly method of pressure measurement using Bourdon type pressure

Fig 10: Fabrication of Assembly method of pressure measurement using Bourdon type pressure

5. Experimental Setup

In short the experimental setup consists of following component: [3]

1. Vapour compression refrigeration unit
   a. Compressor
   b. Condenser
   c. Expansion device (capillary tube)
   d. Evaporator
2. Energy meter
3. Five thermo-couple with digital display
4. Two pressure gauge
5. Main switch & indicator

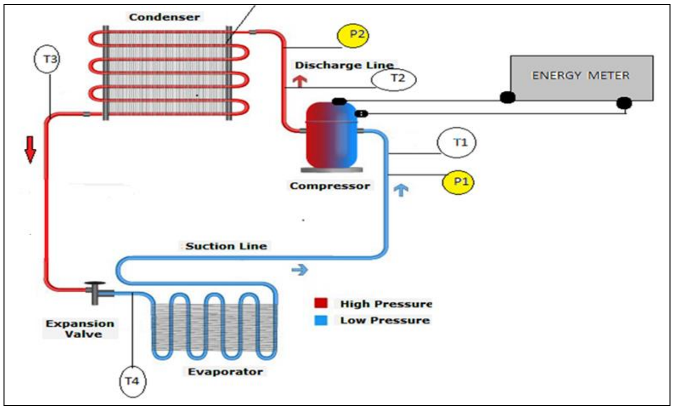
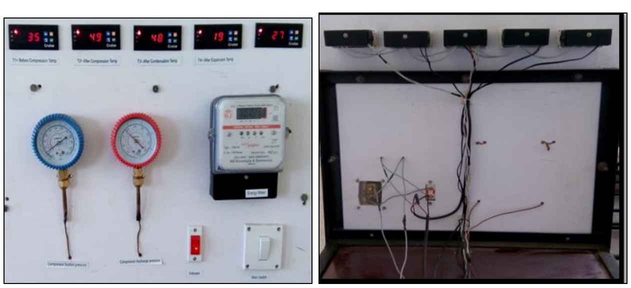


Fig 11: schematic dia1gram of a refrigeration system experimental set-upsystem

a. Front view b. Back side view



c. Reading panel Front view **d.** Reading panel Back side view

Fig 12: Actual Experiment Set-up

5.1 Experimental procedure

As a first step, R-134a is used as a working fluid at room temperature of 20C. Pressure and temperature in the inlet and outlet of the compressor, condenser pressure and temperature, evaporator outlet temperature are monitored in every one hour. The Compound pressure gauge and temperature sensors are mounted on the both ends of the compressor and condenser to measure the pressure and temperature of the refrigerant respectively. Finally COP and Mass flow rate is evaluated for the working fluid R134a. Then working fluid is released to the ambient and it can be fully evacuated by using vaccum pump running for three hours. R32/R600a/R290's are mixed in the proportions of 70%/5%/25% used as refrigerant in the refrigerator. The Same procedures are repeated to calculate the COP and Mass flow rate for those mixtures of gases.

6. Summary

By reviewing all these research work and by study of various thermodynamic properties of the refrigerants as Given in Different Research Paper, According to Montreal and Kyoto protocols, R12 should have been phased out by 2010 and the consumption of R134a must be reduced. R600a, R290 and blends of R290 and R600a are the better option for the replacement ofR134a in domestic refrigerator, due to their low global worming potential (GWP) and zero ozone depletion potential (ODP). Selecting various charge mass of R600a, R290 and hydrocarbon mixture, and their experimental analysis were carried out.

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