# EXPERIMENTAL ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM WITH R134a AND R404a MIXED IN DIFFERENT PROPORTIONS

**M. Venkatakrishna Reddy, Dr. P. Vijay Kumar**

Department of Mechanical Engineering

Lakireddy Balireddy College of Engineering (Autonomous), Mylavaram, India.

## Abstract

In the present environmental concerns natural refrigerants (HC, CFC's) have attracted the researchers due to remarkable refrigerant contributions to global warming and ozone depletion issues. Hence, using alternative refrigerants to control the ODP and GWP has been the burning research area around the globe. In India, 70% domestic refrigerators use HFC134a gas. It has excellent physical and thermodynamic properties. An attempt is made to investigate alternative (Blends) refrigerants performance experimentally in the present work. The aim of the project is to increase COP of a VCR system using HFC's R134a and R404a blends by simultaneously comparing CFC12 in VCR system at steady state conditions. In this system measuring various performances like refrigerating effect, pressure ratios. CFC12 having harmful to environment and it have some ODP &GWP. But R134a & R404a gases are Eco-friendly to environment. So it was mainly focused on finding alternative refrigerants in the market. The performance of refrigerants of R134a and R404a mixtures (25%+75%, 50%+50%, 75%+25%) proportion by mass was used in a vapour compression refrigeration system to investigate its performance. The new blends taken in the above proportions were found promising in giving better performance compared to existing refrigerants. Also a comparison is made for the performance between three refrigerants R12, R134a and R404a respectively.

**Key Words:** GWP, ODP, COP, Alternative refrigerants, Refrigerating effect

**Nomenclature**

| | |
|---|---|
| COP | Coefficient of performance |
| CFC | Chlorofluorocarbons |
| HFC | Hydrofluorocarbons |
| $h_1$ | Enthalpy of saturated Vapour at exit of evaporator |
| $h_2$ | Enthalpy of saturated Vapour at exit of Compressor |
| $h_4$ | Enthalpy of saturated liquid at exit of Expansion value |

| | |
|---|---|
| R134a | Tetrafluoroethane |
| R12 | Dichlorodifluoromethane |
| R404a | Hydrofluorocarbon |
| $R_e$ | Refrigerating Effect (Q) |
| V | Voltage (Volts) |
| I | Current(Amps) |

## 1. INTRODUCTION

Now a days, the most effecting problem is ozone depletion and global warming by using natural refrigerants i.e. hydrocarbons (HC) and chlorofluorocarbons (CFC). These are populated from many industries and domestic refrigerators and many purposes. The hydrocarbon refrigerants contain no chlorine and no fluorine atoms, it releases harmful gases to environment and it was polluted. In that time some scientists investigate to launch eco friendly refrigerants and it is called alternate refrigerants. It will protect nature and zero ozone depletion potential such as HFC refrigerant. HFC134a is replacement refrigerant for CFC12 because its have a useful characteristics such as non-flammability, non-corrosive, non-toxicity, zero ODP, stability and etc. In a vapour compression refrigeration system, it is a heat rejected from the atmosphere temperature to low temperature in the space. R134a having good thermodynamic and physical properties and also R404a refrigerant have same properties like R134a. in VCR system using R134a & R404a refrigerants proposed to use small refrigeration systems.

**Table 1: Properties of R12, R134a and R404a refrigerants**

| Refrigerant | R12 | R134a | R404a |
|---|---|---|---|
| **Chemical composition** | $CCl_2F_2$ | $CH_2FCF_3$ | $CHF_2CF_3CH_2FCF_3CH_3CF_3$ |
| **Critical temperature ($^oC$)** | 110 | 101.06 | 127.24 |
| **Normal boiling point ($^oC$)** | -21.6 | -26.08 | -47.7 |
| **Critical pressure (MPa)** | 4136 | 4059 | 4956 |
| **Ozone layer depletion** | 1 | 0 | 0 |
| **Global warming potencial** | 10910 | 1300 | 3260 |

| | | | |
|---|---|---|---|
| **Molecular Weight (g/mol)** | 120.9 | 102.03 | 97.6 |
| **Environmental classification** | CFC | HFC | HFC |

**2. Vapour Compression Refrigeration System:**

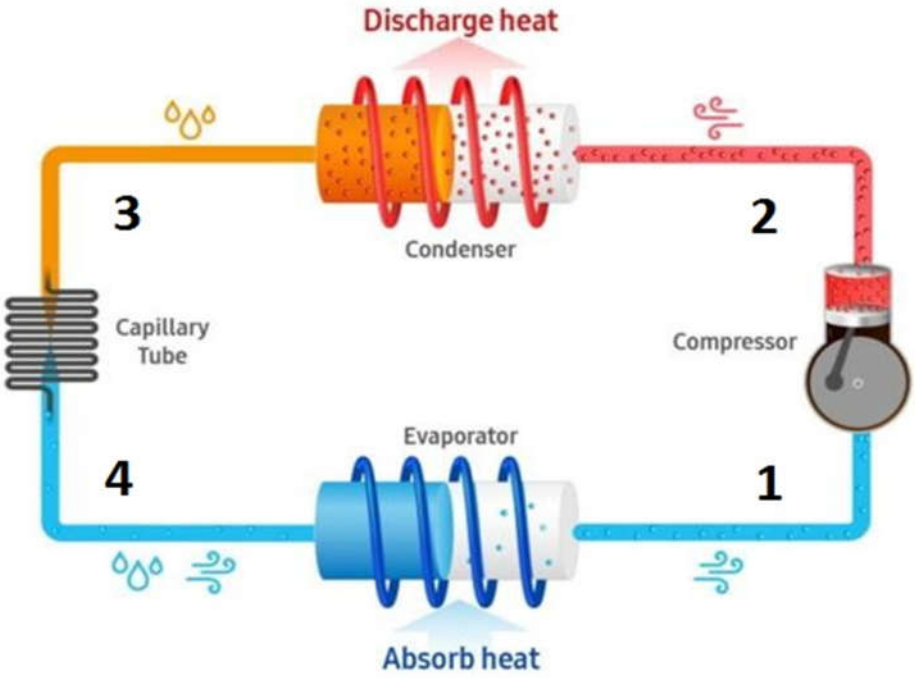


**Figure 1: Vapour Compression refrigeration cycle**

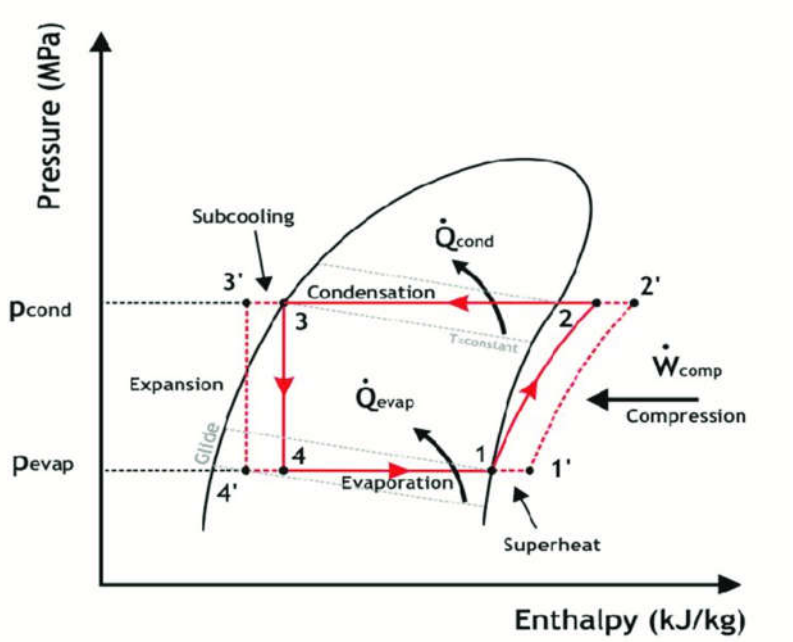


**Figure 2: P-h diagram of VCR system**

The vapour compression system is running of refrigerant to circulate the system it absorb and remove heat from the space and automatically cooled to the space. In VCR system having four main components are working in this system. These four components are compressor, condenser, expansion value and finally evaporator.

In VCR system, working between four cycles they are,

Cycle 1-2: Compression process

Cycle 2-3: Heat rejection or Condensation process

Cycle 3-4: Expansion process

Cycle 4-1: Heat addition process

### 2.1 Compression process:

The isentropic compression process the liquid refrigerant which is at low temperature and low pressure in evaporator flows into the compressor. In the compressor converted into high temperature and high pressure. This compressed vapour passes through condenser.

### 2.2 Heat rejection or Condensation process:

In heat rejection process the high pressure and high temperature vapour from compressor to enter the condenser and it converted into low temperature and constant pressure. So the refrigerant will condense to its liquid state.

### 2.3 Expansion process:

In this process, constant pressure and low temperature of liquid vapour enters to the expansion value and its converts to low pressure and low temperature of liquid refrigerant.

### 2.4 Heat addition process:

This process, low temperature and low pressure of liquid refrigerant enters to the evaporator and the heat absorb from the surrounding location or medium which is to be cooled. Then it is covert to vapour passes through compressor.

The coefficient of performance COP is defined as a heat pump, refrigerator or air conditioning system is a ratio of useful heating or cooling provided to work required.

COP = Refrigerating effect / Work input

The theoretical COP is higher than the Actual COP is found by performance of this experimentation setup.

### 2.5 Refrigerants usage for various applications:

A refrigerant is a substance or mixture, usually a fluid, used in a refrigeration and heat pump cycle. In most cycles it undergoes phase changes from a liquid to a gas and back again. Many working fluids have been used for many purposes. Fluorocarbons, especially chlorofluorocarbons, became commonplace in the 20th century, but they are being phased out because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane.

#### 2.5.1 Chlorofluorocarbon (R12):

In this refrigerant most of the people using for refrigerators and air conditioners. But this CFC refrigerant have high ozone depletion potential (ODP) and global warming potential (GWP). It was harmful to environment.

#### 2.5.2 Tetrafluoroethane (R134a):

This refrigerant having good thermodynamic and physical properties. It is used for alternate refrigerant by replacing of R12refrigerant. Because it have same properties like R12 refrigerant but this gas was Hydro fluorocarbon and it have such a favorable characteristics like zero ozone depletion (ODP), global warming potential, stability, non flammability, etc. this is environmental friendly refrigerant.

### 2.5.3 Hydrofluorocarbon (R404a):

R404a is a blended composition of HFC refrigerants i.e. R125, R143a, R134a by the composition (44%+52%+4%) of weight ratios. It is a eco-friendly refrigerant and zero ODP and non flammability, stability. The mixing refrigerant gives better results compare to the CFC refrigerants.

## 3. Literature Review

[1] In 2006, Tejaswi saran pilla & Pranay kumar goud sunkari investigates experimental evaluation and performance of the compressor with mixed refrigerants R290 and R600a to improve the Coefficient of performance by taking different wt %.[2] Mitesh M. deshmukh and K.V. mali in 2005, investigate performance comparison of R22 refrigerant with alternative hydrocarbon refrigerants to be increasing refrigerating effect and coefficient of performance.[3] Pannerselvam S, investigates performance characteristics of refrigerant blends in vapour compression refrigeration system and improve the Coefficient of performance.[4] D. Ramesh, M.Sudhagar and E. Sathees kumar, investigates performance of VCR system by taking refrigerant blends and finally conclude with energy improve COP consumption.[5] A. Baskaran, P. Koshy Mathews investigates performance of VCR system using Eco Friendly refrigerants R134a. and he is find alternate refrigerant RE170 mixed to R134a to be decrease the ozone depletion.

## 4. Design and Experimental Setup

In a vapour compression refrigeration system has to be made up of different devices can be used and it was connected and placed in a flat table. The $1/8^{th}$ HP compressor working on this system. In this system capacity of the evaporator is 8 liters. Using Air-cooled condenser can be working for more heat can be eliminated on hot refrigerant vapour after leaving compressor. This system expansion process has to be run by using capillary tube and finally filter dryer also placed on this system because this filter stops dust particles and spices then working fluid runs perfectly.

In this system using two pressure gauges because of measuring suction and delivery pressure of the compressor has to be placed on before suction line and after delivery line of the compressor. By using two values has to be placed on suction line and delivery line of the compressor. The experimental setup has to be ready for experimentation with no refrigerant leakages of this vapour compression refrigeration system.

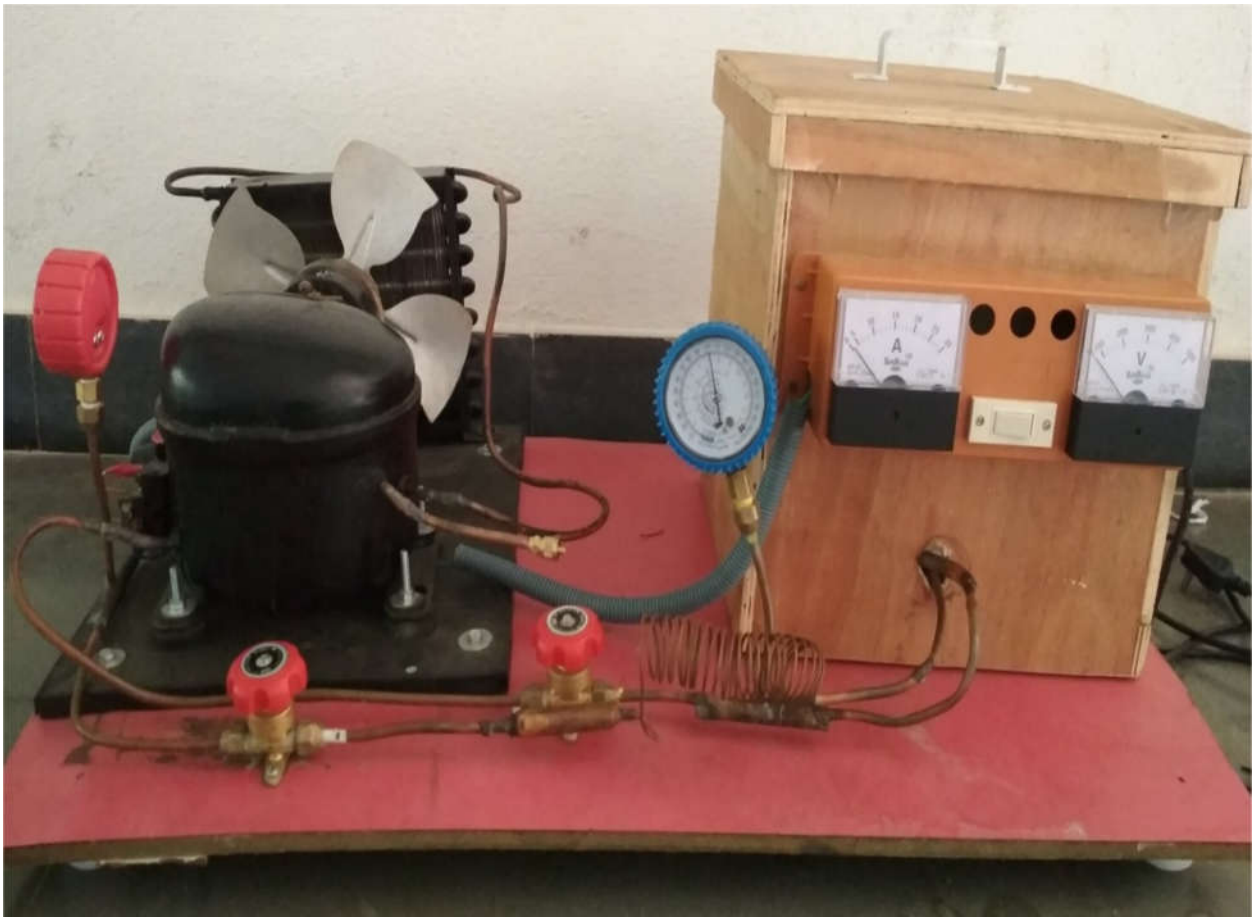

**Figure 3: Photographic view of VCR experimental set up**

## 5. Experimental Procedure

In this system using R12 refrigerant (120g) to filled with compressor and run the system. Note down starting time, thermocouples and pressure gauge readings. Run the system for 1 hour and take readings for every 10 minutes. After completion of experiment then remove refrigerant from the compressor and then filled on R134a refrigerant(120g). Then run this system and note down readings as usual. Remove the refrigerant and then fills on R404a refrigerant(120g) in this system. Using this R12, R134a & R404a refrigerants working on vapour compression refrigeration system it gives performance of their standards. Then applying mixed refrigerants (R134a & R404a) on different weight ratios to the compressor and it will gives their working performance on this vapour compression refrigeration system.

By taking mixed refrigerant weight ratios of these two refrigerants as shown below.

Blend 1: 75% of R134a & 25% of R404a

Blend 2: 50% of R134a & 50% of R404a

Blend 3: 25% of R134a & 75% of R404a

After applying this blends on compressor while note down readings and calculating the performance of various parameters like **Refrigerating effect, TOR, Actual COP, Theoretical COP, Relative COP and finally Refrigerating Effect Rate.**

## 6. Solution Methodology

1. Refrigerating Effect ($R_e$) = $m_w c_{pw} dt$, (Kj)
2. COP = Refrigerating Effect ($R_e$) / work input ($W_{i/p}$)
3. Theoretical COP = $(h_1-h_4)/(h_2-h_1)$
4. Relative COP = Actual COP / Theoretical COP
5. Power(P) = V * I, (watts)
6. Energy input $E_{i/p}$ = P*T, (Kj)
7. Refrigerating Efficiency = Relative COP * 100, (%)
8. Refrigerating Effect Rate (RER) = $R_e/T$

## 7. Results and Discussions

This project work deals with CFC, HFC and HFC mixed refrigerants in order to their feasibility for vapour compression refrigeration system by comparing their relative parameters.

**Table 2: Performance of various parameters using mixed refrigerants**

| Refrigerant | Refrigerating Effect (Kj) | TOR | Actual COP | Theoretical COP | Relative COP | Refrigerating Effect Rate(Kj/min) |
|---|---|---|---|---|---|---|
| **R12** | 764.96 | 0.0607 | 1.207 | 2.871 | 0.4204 | 12.74 |
| **R134a** | 791.34 | 0.0626 | 1.248 | 2.959 | 0.4217 | 13.19 |
| **R404a** | 867.54 | 0.0682 | 1.369 | 2.877 | 0.4758 | 14.45 |
| **R134a+R404a (75% + 25%)** | 814.79 | 0.0646 | 1.285 | 2.939 | 0.4390 | 13.57 |
| **R134a+R404a (50% + 50%)** | **946.68** | **0.0751** | **1.494** | **3.007** | **0.4980** | **15.77** |
| **R134a+R404a (25% + 75%)** | 779.61 | 0.0618 | 1.230 | 2.690 | 0.4570 | 12.99 |

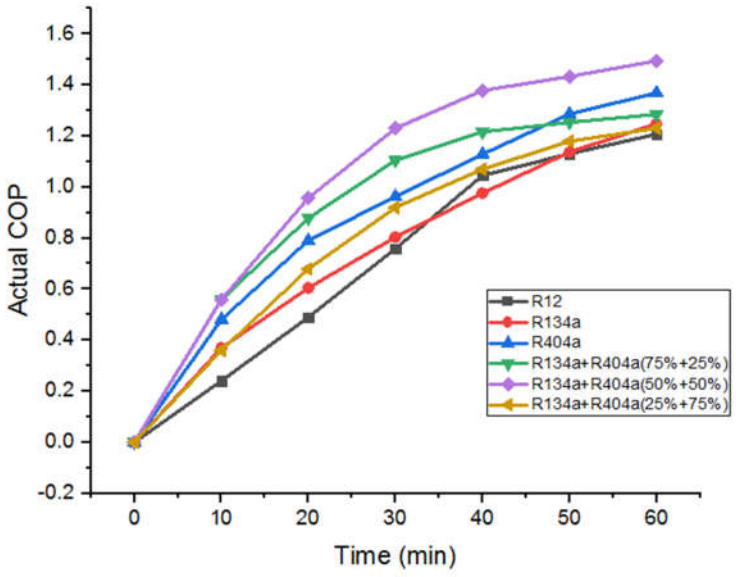


**Figure 4: Variation of experimental actual COP for different refrigerant mixing proportions**

In the figure 4 shows variation of actual COP between mixed refrigerants and pure single refrigerants. The R134a and R404a (50%+50%) blend gives best performance of blended refrigeration system is high compared to the single pure refrigerants and remaining blending proportions.

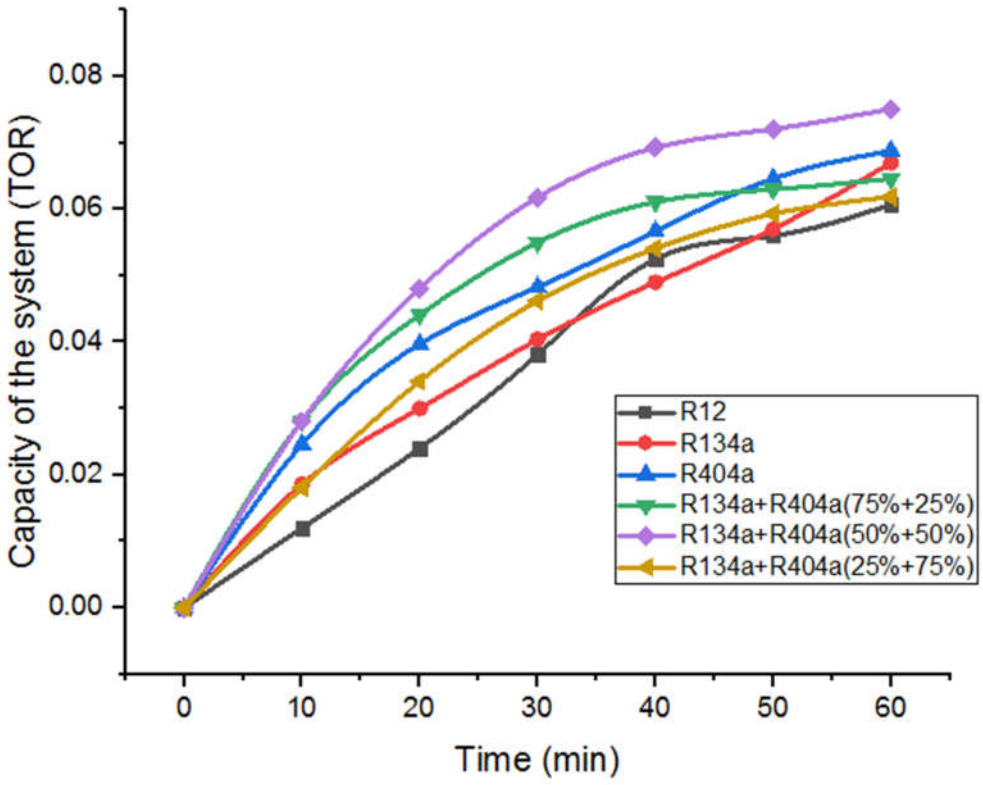


**Figure 5: Variation of experimental Capacity of the system for different refrigerant mixing proportions**

Figure 5 shows variation of Capacity of the system between mixed refrigerants and pure single refrigerants. The R134a and R404a (50%+50%) blend gives best performance of blended refrigeration system is high compared to the single pure refrigerants and remaining blending proportions.

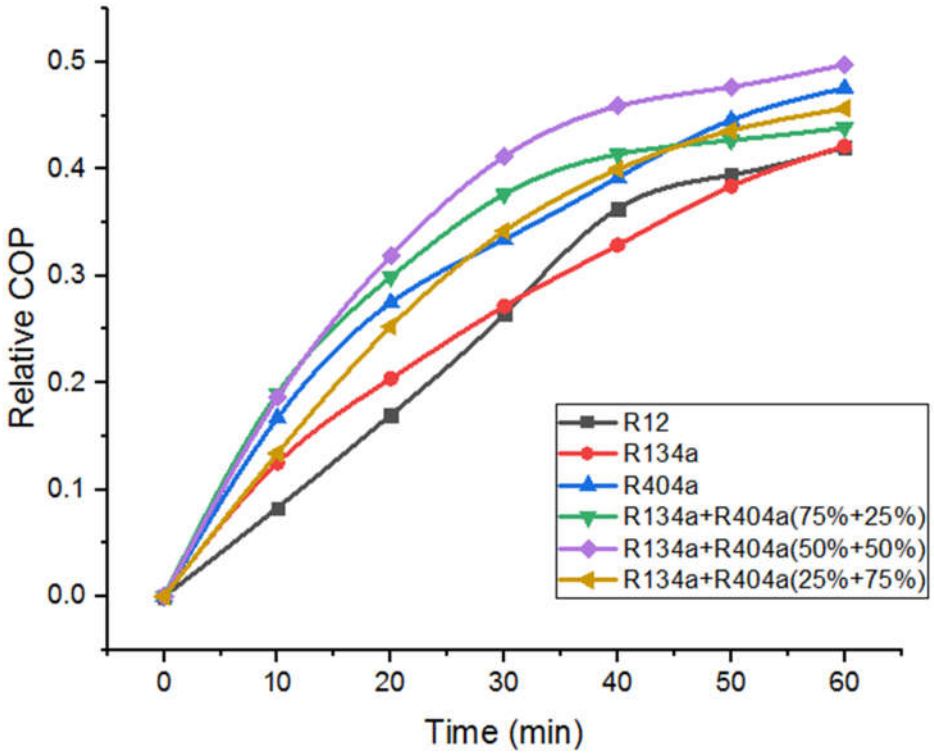


**Figure 6: Variation of experimental relative COP for different refrigerant mixing proportions**

Figure 6 shows variation of Relative COP between mixed refrigerants and pure single refrigerants. The R134a and R404a (50%+50%) blend gives best performance of blended refrigeration system is high compared to the single pure refrigerants and remaining blending proportions.

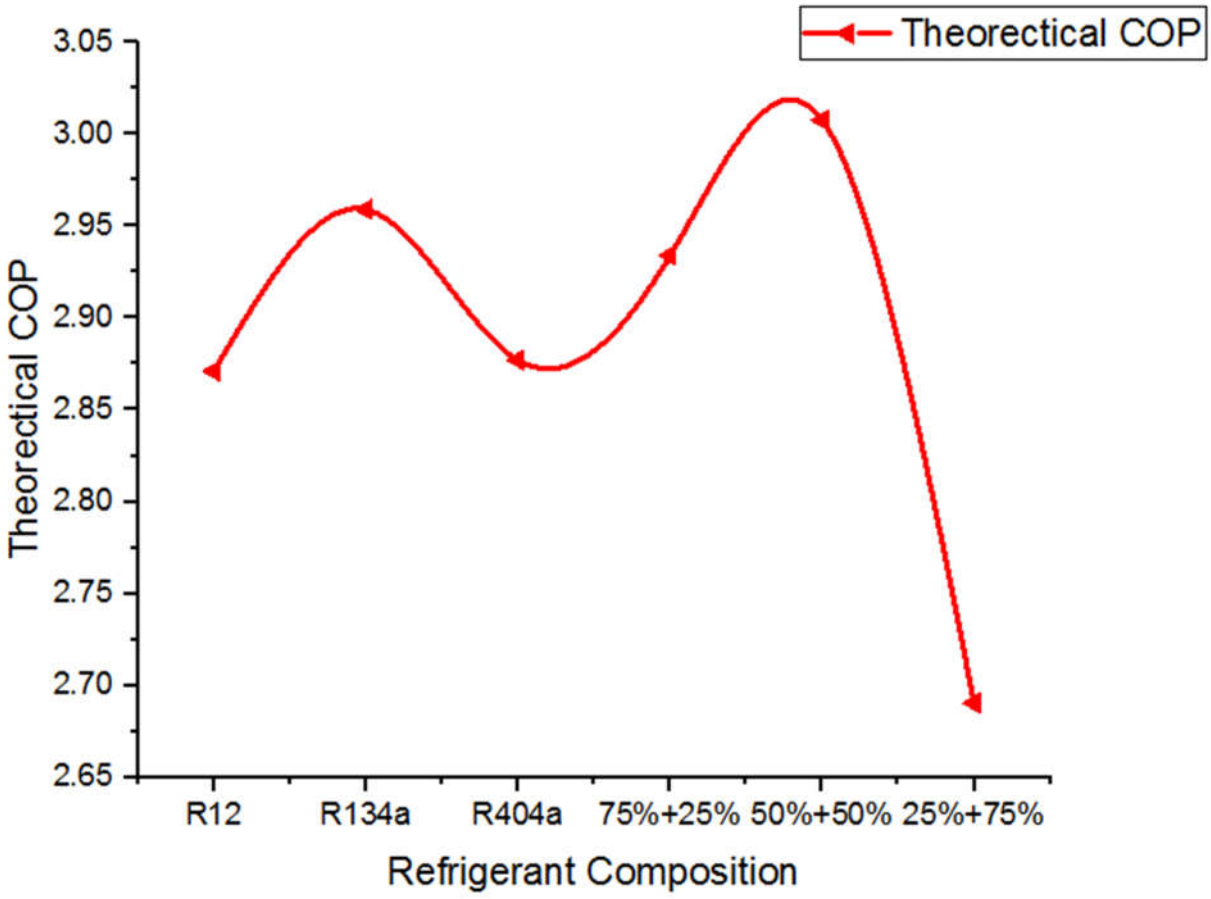


**Figure 7: Variation of Theoretical COP for different refrigerant mixing proportions**

Figure 7 shows variation of Theoretical COP between mixed refrigerants and pure single refrigerants. The R134a and R404a (50%+50%) blend gives best performance of blended refrigeration system is high compared to the single pure refrigerants and remaining blending proportions.

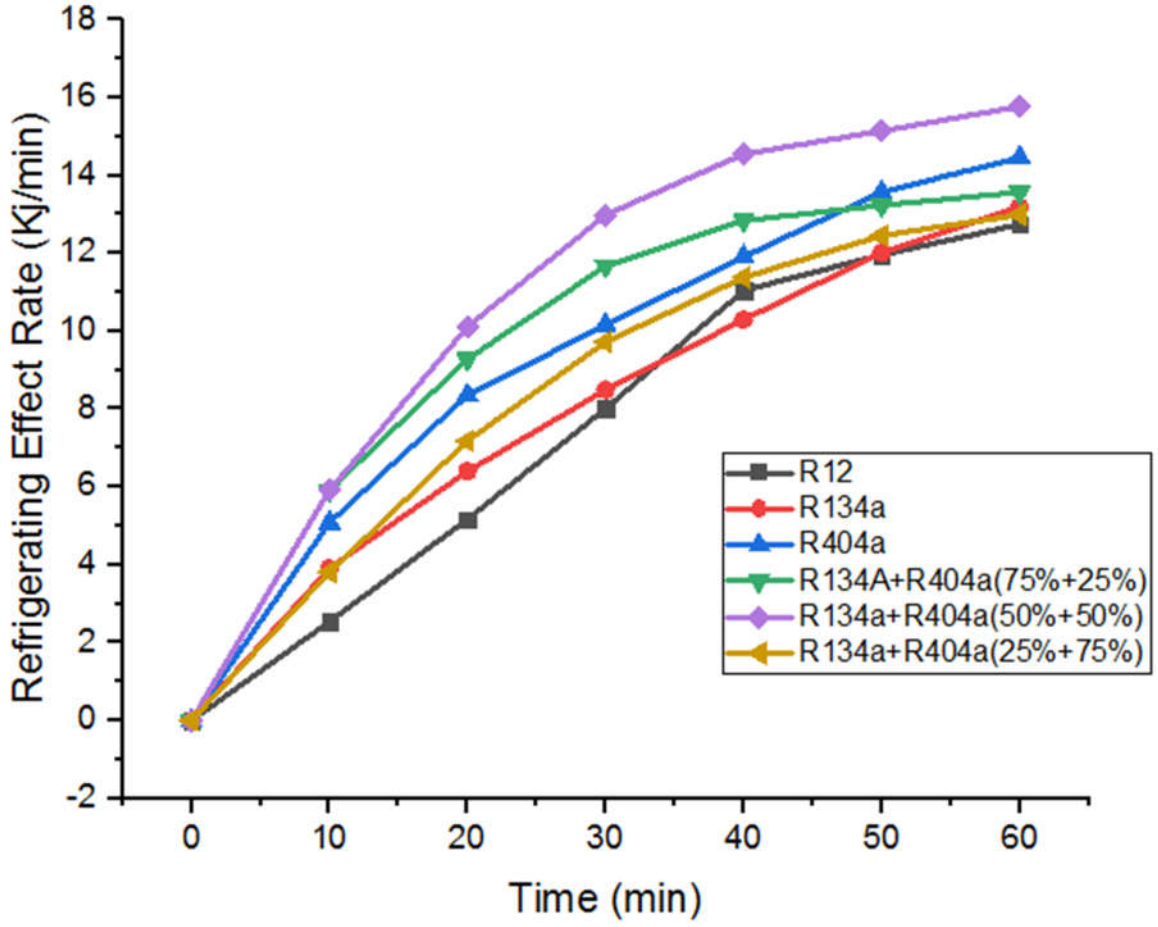


**Figure 8: Variation of experimental Refrigerating effect rate for different refrigerant mixing proportions**

Figure 8 shows variation of Refrigerating effect rate between mixed refrigerants and pure single refrigerants. The R134a and R404a (50%+50%) blend gives best performance of blended refrigeration system is high compared to the single pure refrigerants and remaining blending proportions.

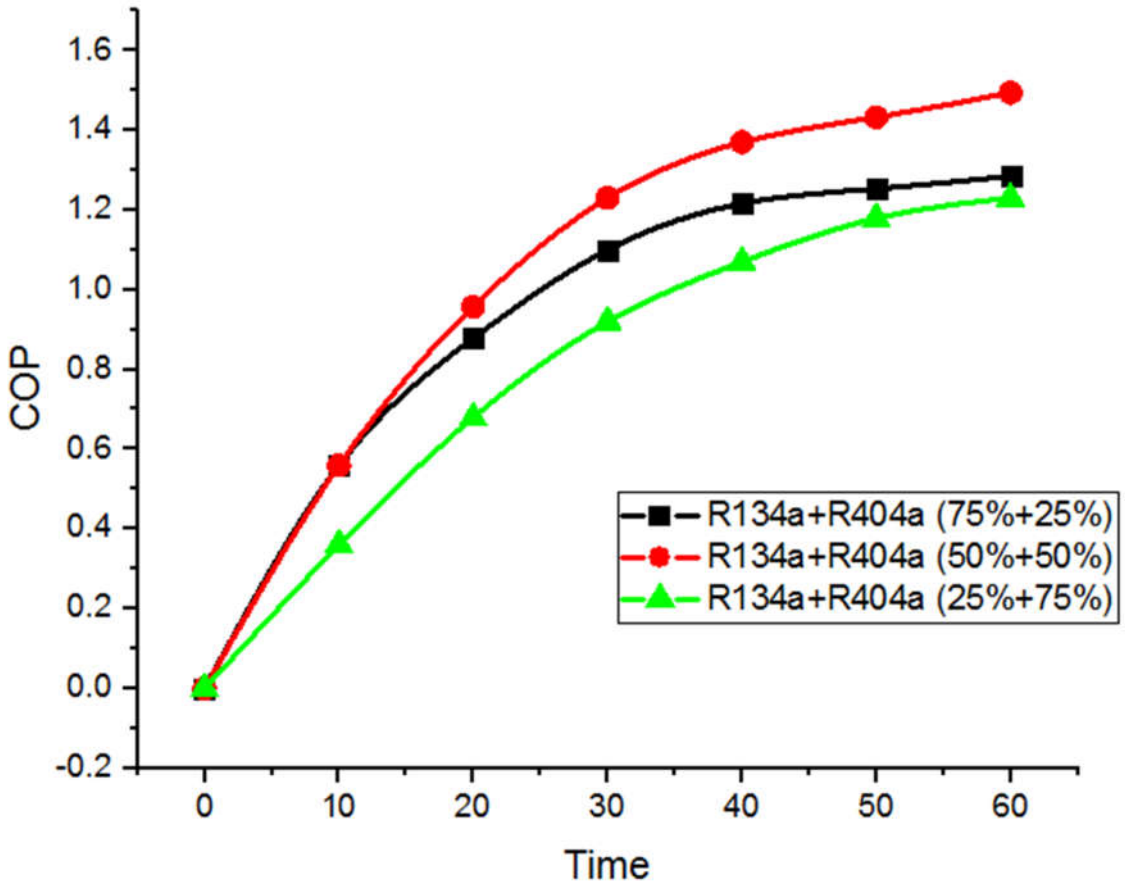


**Figure 9: Comparison of COP Performance for Mixed Refrigerants**

Figure 9 shows variation of Refrigerating effect rate between mixed refrigerants. The R134a and R404a (50%+50%) blend gives best performance of blended refrigeration system is high compared to remaining blending proportions.

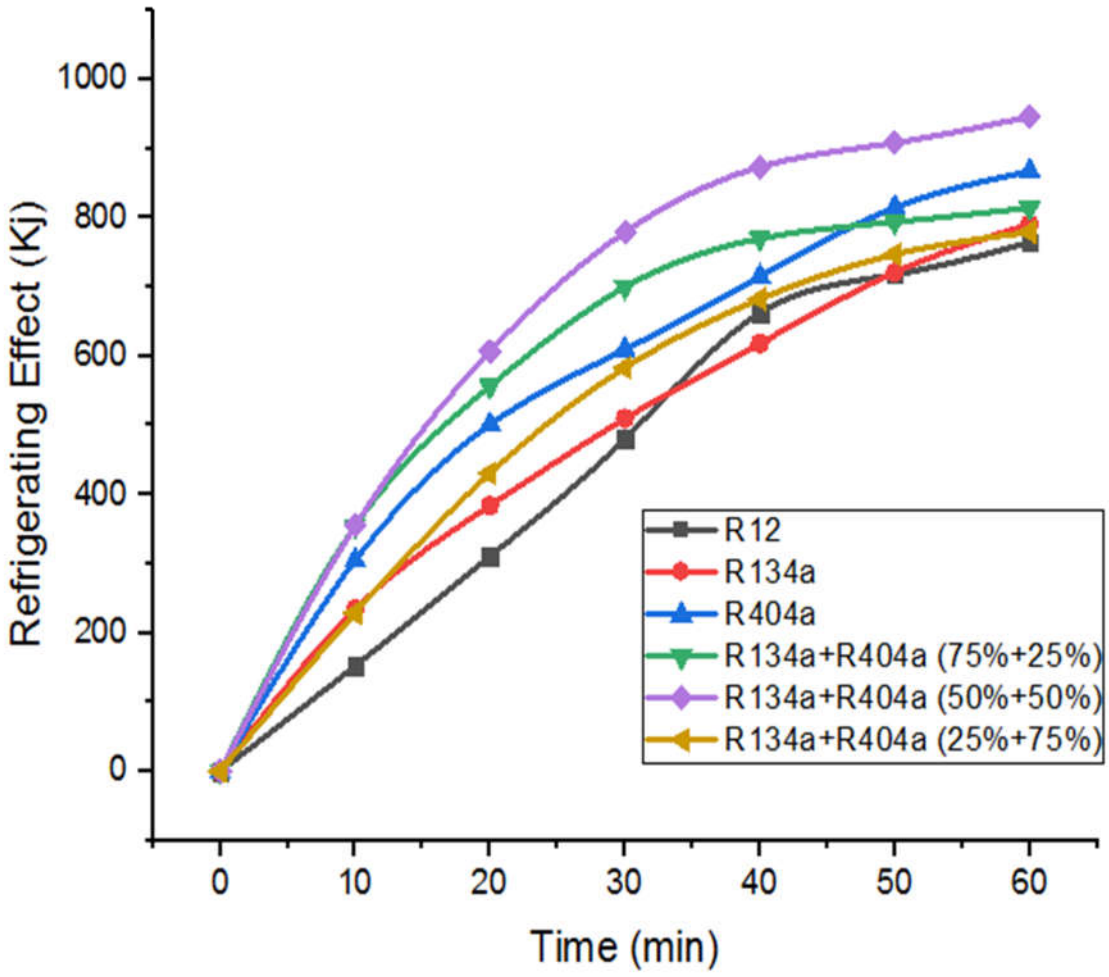


**Figure 10: Variation of experimental Refrigerating effect for different refrigerant mixing proportions**

Figure 8 shows variation of Refrigerating effect between mixed refrigerants and pure single refrigerants. The R134a and R404a (50%+50%) blend gives best performance of blended refrigeration system is high compared to the single pure refrigerants and remaining blending proportions.

This experiment was run based on the standard methods without modifying the components of refrigerators. In this system observing comparative performance between R12, R134a and R404a refrigerants respectively. The mixed refrigerants have been tested and found to be performed better in a vapour compression refrigeration system with different weight proportions.

## 7. CONCLUSIONS

The investigations were made in a vapour compression refrigeration system using different refrigerant mixures taken in different proportions and the performance studied experimentally. The selected refrigerants are environmentally, eco-friendly, energy efficient, safe alternative refrigerants namely R134a and R404a used in vapour compression refrigeration system experimental set up. After the successful investigation on the performance of individual R134a and R404a then blends have been prepared in 25%+75%, 50%+50% and 75%+25% respectively and results are obtained. The actual COP has increased for mixed refrigerant R134a+R404a (50%+50%) compared to other blends and R12, R134a and R404.It is concluded that there is an increase in refrigerating effect, theoretical COP and refrigerating rate. The drawback of HFC mix refrigerant is having Global warming potential. The composition of blend R134a+R404a (50%+50%) found to be eco friendly alternate refrigerant for a VCR system. The investigations may be further extended to use other mixtures of R404a/R134a for further improvement of energy efficiency of the new blend..

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