EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE OF DOMESTIC REFRIGERATION SYSTEM OPERATED ON SOLAR ENERGY WITH MIXED REFRIGERANT

Dissertation-II

Submitted in partial fulfillment of the requirement for the award of degree of

**Master of Technology**

**IN**

**MECHANICAL ENGINEERING**

By

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Under the guidance of

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# DEPARTMENT OF MECHANICAL ENGINEERING

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## CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "Experimental investigation on the performance of domestic refrigeration system operated on solar energy with mixed refrigerants" in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of Assistant professor Jai kishor Verma Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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The external viva-voce examination of the student was held on successfully ________________

Signature of Examiner

LOVELY PROFESSIONAL UNIVERSITY

**TOPIC APPROVAL PERFORMA**

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**PROPOSED TOPIC :** Experimental investigation on the performance of domestic refrigeration system operated on solar energy with mixed refrigerants.

| Qualitative Assessment of Proposed Topic by PAC | | |
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| **Sr.No.** | **Parameter** | **Rating (out of 10)** |
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| 2 | Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students. | 6.50 |
| 3 | Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program. | 7.25 |
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| 5 | Social Applicability: Project work intends to solve a practical problem. | 7.50 |
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This project consumed lot amount of work, research and dedication and may as per as globally needed requirements. Secondly I would also like to thank my parents and friends who helped me a lot in doing my dissertation work within the limited time frame.

## DECLARATION STATEMENT

This thesis is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

The work was done under the guidance of Assistant Professor Jay Kishor Verma at the Lovely Professional University, Phagwara.

Gagandeep Singh Kajal

In my capacity as supervisor of the candidate's thesis, I certify that the above statements are true to the best of my knowledge.

Assistant Prof. Jai Kishor Verma

**Index**

- List of Contents
- List of Figures
- List of Tables

**List of contents**

**List of figures**

**List of tables**

**Abstract**

Hydrochloroflourocarbons are contributing to Ozone depletion due to the formation of perchlorate. This in turn allows ultraviolet rays reach the surface, causing destructive effects on animal life. Hence, there is a need for the development of new refrigerants which does not affect the environment.

In the present work, an experimental investigation is planned to estimate the performance of domestic refrigerator operated on solar photovoltaic cells. Further, a mixed refrigerant is chosen at different volumetric compositions as working fluid. Moreover, Levelized cost of energy (LCOE) is to be estimated which signifies the equivalents energy in terms of cost of the system.

As another prospective the selection of different hydrocarbons is planned to analyze for substitution of hydrochloroflourocarbons with a suitable mixed refrigerant contains appropriate volumetric composition.

Further, a comparative study is planned to exhibit various performance characteristics of domestic refrigerator such as coefficient of performance (COP), work done on the compressor with different volumetric compositions of working fluid.

# 1 Introduction

Refrigeration is the process of transfer of heat between two locations and removing heat from any system to reach temperature below environment temperature. The refrigeration system outcomes in terms of storing of food products for finite time having in low temperature conditions. Refrigeration provides applications in areas like domestic refrigerators, industrial freezers, cryogenics and air conditioning.

## 1.1 Methods of Refrigeration

### 1.1.1 Natural Refrigeration

The natural approach deals with naturally availability of ice or snow during the cold climate conditions. As we know, the melting of ice is at $0^0$C. So while placing in the environment warmer than $0^0$C and cooling is provided by the absorption of heat. The melting of ice into water is to be there by absorbing latent heat. Moreover, in the present time, due to continuity of increment in refrigeration into the high level that the natural approach are deficient and therefore outmoded.

### 1.1.2 Mechanical or Artificial Refrigeration

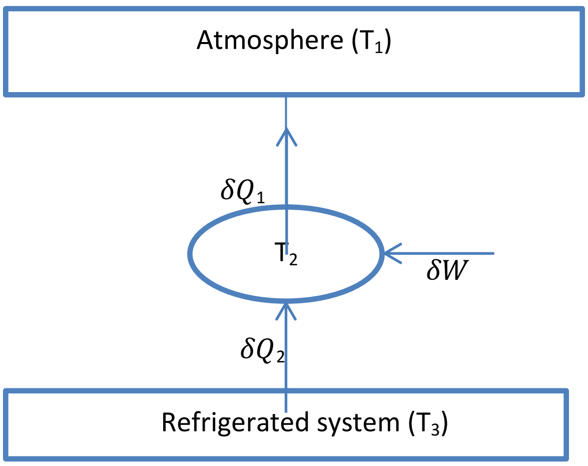


**Figure 1.1: Reversed Carnot engine**

A mechanical refrigeration system is to be shown in figure 1.1 and its working is based on the reversed Carnot cycle. So, work $\delta w$ is to be provided to the refrigeration system which detaches heat $\delta Q_2$ from the system which is at temperature $T_2$ and to distribute it also with work, to higher temperature $T_1$ system.

$$\delta Q = \delta w + \delta Q_2$$

While consideration of this method, following are the types of mechanical refrigeration system:

**1.1.2.1 Air systems:** In this method of refrigeration, working fluid is air. Moreover, air as a working fluid termed as no change of phase, but due to the temperature difference absorption of heat is to be there.

**1.1.2.2 Chemical Agent Systems:** In this method, the boiling of fluid is to be there which provides in change of phase and absorbs the latent heat.

## 1.2 Refrigerating Machine

A system that regulates controls and maintains a body at a lower potential with relevance that of the encompassing is termed as a cooling. Heat flows from a body of lower temperature to the encompassing is termed as a cooling. Heat flows from a body of lower temperature to the encompassing higher temperature bodies. This flow of temperature from an occasional potential body to a high potential space isn't attainable unless and until an external force is applied. Therefore we tend to apply external force to create a cooling in method.

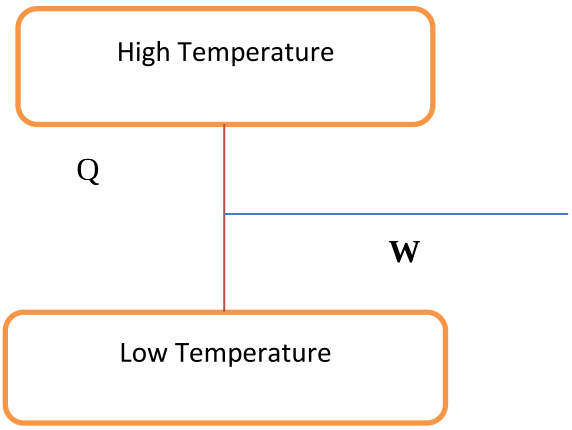


**Figure1.2: Schematic representation of Refrigerating Machine**

The schematic diagram of refrigerating machine is to be shown in figure1.2. Our refrigeration system conjointly provides thermal comfort to people in general by means that of air conditioning. It conjointly preserves spoilable food product by storing them at low temperatures. An icebox could be a system that takes temperature from an occasional potential cold body to a high potential hot encompassing supported the Second law of Thermodynamics.

## 1.3 Types of Refrigeration system

Refrigeration systems are of two types and which are shown below

1. Conventional
2. Non-conventional

### 1.3.1 Vapour Compression Refrigeration System

Vapour Compression Refrigeration system defines by the other name as domestic refrigeration system and provides its existence frequently in refrigeration system. The usage of refrigerant provides change in phase and whose existence commonly in domestic in addition commercial refrigerators for many requirements like as storing of food and other materials. Our vapor compression system circulating liquid refrigerant for absorb and removal of heat from the reference area and rejects that heat somewhere else. The main components of VCRS are Compressor, Condenser, Expansion valve and Evaporator etc.

### 1.3.2 Vapour Absorption Refrigeration System

Vapour Absorption Refrigeration System (VARS) is termed as similar to Vapour Compression Refrigeration System (VCRS). Our absorption refrigeration system by using a heat source in any form like solar energy for providing energy required for cooling. Moreover, in VAR system the mainly heat required in the inlet and which referred as low grade energy. So, another term which also defines this system is heat operated system and the preference of these systems is only dependent on solar energy.

## 1.4 Major components of VCR system

Vapour compression refrigeration system consists of four major parts and which are discussed below

1. Compressor
2. Condenser
3. Expansion device
4. Evaporator

The refrigeration system as per components is arranged in figure 1.3. Our system having showing four processes which are inlet from the compressor and those are discussed below:

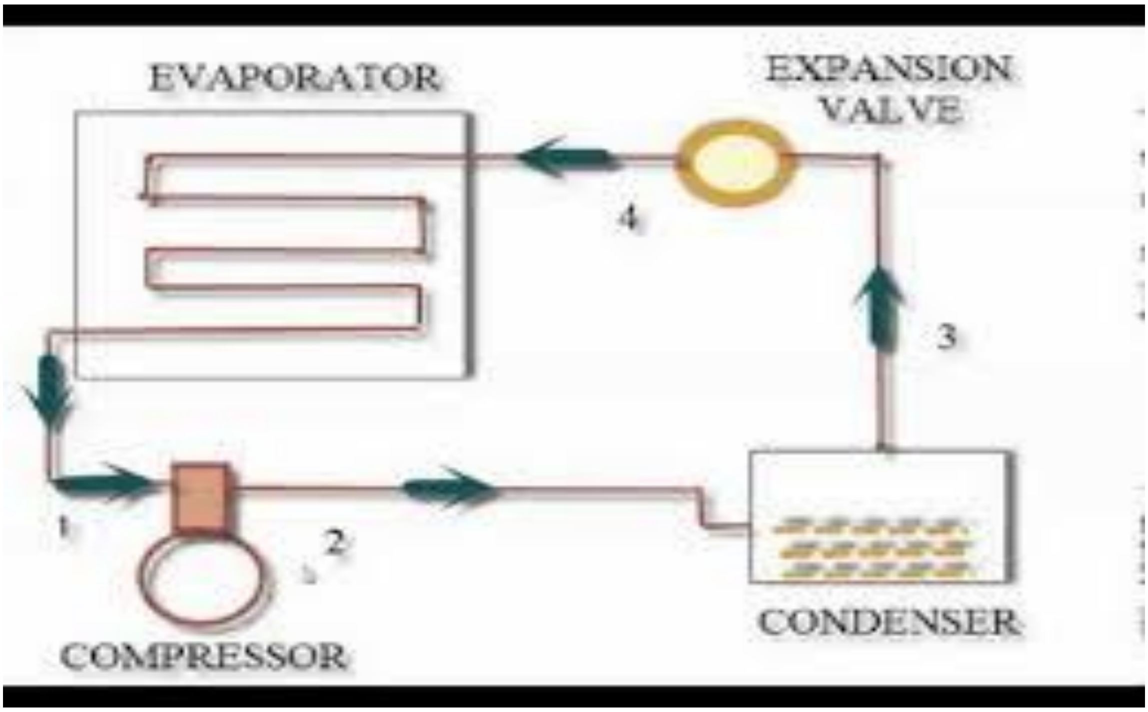


**Figure 1.3: Schematic diagram of VCRS**

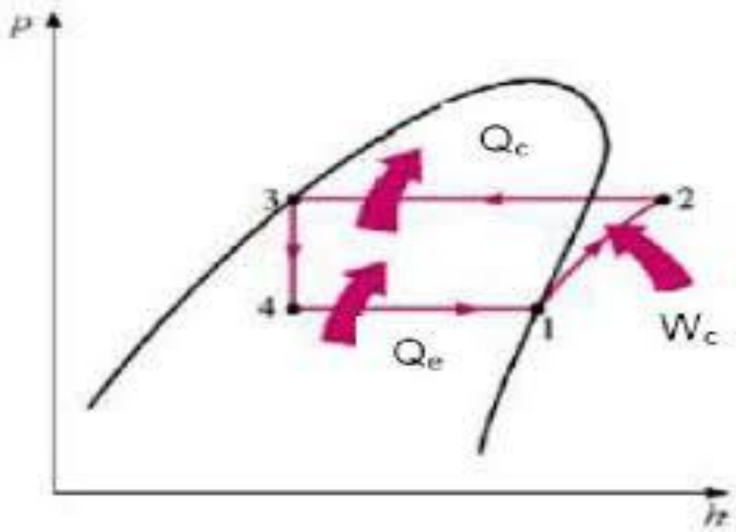


**Figure 1.4: P-h graph of VCRS**

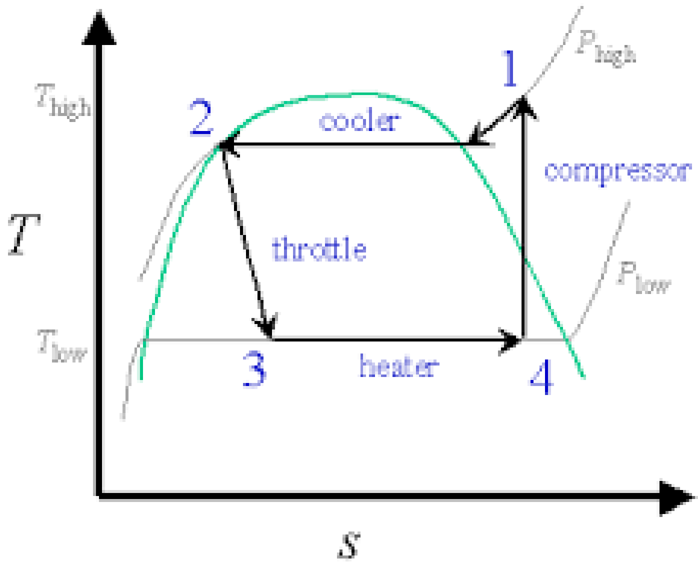


**Figure 1.5: T-S graph of VCRS**

## 2 Scope of study

The scope of the study mainly concerns the following areas and aimed to answer these questions:

- Advancement of VCR system with the use of blend of refrigerant?
- Properties and parameters to be considered in mixing of refrigerants of any kind?
- The effects of various properties on mixture?
- The utilization of power of the mixed refrigerant and its impact on system?
- The compatibility of the elements of the system?
- The refrigeration effect of the VCRS how much with the use of mixed refrigerant?
- The impact of COP with different proportions of different refrigerants?

The mixing of refrigerants with each other is possible and they are defined as mixed refrigerants. The properties like thermal, chemical, a thermo-physical and environmental of the investigated blend changes while comparing with initial pure refrigerant mixed.

Our investigation is to be referred to the mixing of these refrigerants R290/R600a/R134a at different volume proportions. This investigation results provides reference for future research and used for expected results.

## 3 Objective of study

The objective of our research includes:

- To the improvement of VCRS during working and while analyzing performance with the use of mixed refrigerants.
- To obtain desire refrigeration effect.
- To achieve higher C.O.P.
- To obtain reduction in power consumption.
- To achieve best alternative and environment friendly refrigerants.
- To provide different volumetric proportions in blend of refrigerants.
- To know the impact on components with the blend of refrigerants.
- To commercialize in domestic refrigerator.

After the investigation work, we can be able to find the optimum volume proportions of the hydrocarbon mixture that produces higher COP, better refrigeration effect, lower power consumption, better performance by the compressor.

# 4 Review of Literature

At the proposal stage of a dissertation, the literature review is the list of possible resources which are relevant for our research work. The work in literature review is to be concern with the all aspects which are related to our dissertation work. There is the list of literature review which shows the globally work regarding our research work and that will be shown in paragraphs with proper outcomes:

**V.Manoj et al.** conducted an analysis due to the bad effect of the previously used refrigerants on an environment in terms of high global warming potential and ozone depletion layer. They observed during analyzing various are refrigerants, the refrigerants having low global warming potential and zero ozone layer depletion use as the best substitute for previously used refrigerant. They observed that hydro fluorocarbons are preferred from the energy efficient point of view but they are restricted in near future because having high global warming potential [1].

**R.Vasanthi et al.** conducting an investigation using low-pressure vessel to improve the performance of a domestic refrigerator. They observed that coefficient of performance of a system is to be varied with respect the use of a receiver in the refrigeration system [2].

**Alptug Yataganbaba et al.** conducting analysis for the vapour compressor refrigerator system for the evaluation of the environmental and economic performance which in terms determined with the help of an exergy analysis. They concluded the dependence of exergy efficiency mainly on evaporator and condenser temperature and after observing different refrigerant R1234ze shows highest exergy efficiency [3].

**Atilla Gencer Devecioğlu et al.** conducted a concern on new generation low GWP value gases due to the previously used CFC and HCFC refrigerants which affect our environment in terms of the ozone layer and global warming. They observe that gases must have better energy characteristics with respect to low global warming potential. They concluded Hydrofluoro-olefin based mixed refrigerant which is having low GWP were investigated as the best alternative refrigerant with respect to the previously used refrigerant. They also concluded that there is no system for the proper working of the vapour compression refrigeration system and require a need of proper gas which will have search in future [4].

**S. Wongwises et al.** analyzed and present an experimental work on hydrocarbon mixture for the replacement of previously used refrigerant. They observed that use of HFC-134a is to be restricted due to their high global warming potential. So in this study researcher targeting the need and fulfillment regarding the domestic refrigerator with the investigation of new refrigerant. They investigated refrigerants like propane, butane, isobutene. Besides, with the consideration of maximum usage of propane least amount of energy consumed per day shown while investigation [5].

**M. Fatouh et al.** conducted experimental study due to the researchers shows the great intention on the previously used refrigerants which are not globally acceptable due to their effects on the environment. They represent the mixture of propane and butane which is termed as Liquefied petroleum gas that was invested as a replacement for R134a.They observe while comparison with R134a same volumetric cooling capacity can be obtained with the use of LPG with an efficient capillary tube length and charge. They also concluded about the improvement in coefficient of performance of domestic refrigeration and energy savings and shorter compressor on time comparison with previously used refrigerant [6].

**M. Rasti et al.** conducted an analysis of experimentation on refrigeration system which is globally acceptable as a major energy consumed appliances during the analysis of the household system. Moreover, in this investigation, they have focused on the concern of the energy enhancement of a domestic refrigerator. They investigated an R436A and R600A refrigerant which shows the decrease in energy consumption in domestic refrigeration when charged with an optimum amount of R436A and R600A. They also focused on the exergy analysis on the refrigerants and observed the maximum exergy destruction occur in the compressor and minimum amount observed in evaporator [7].

| Refrigerant | Energy consumption(KWh) | On time ratio(%) | On time period (min) |
|---|---|---|---|
| R436A | 0.1069 | 41.4 | 41 |
| R600a | 0.1031 | 50.9 | 56 |

**Table 4.1: Energy consumption, ON time ratio, and ON time period for different refrigerants in refrigeration system.**

**Kumar et al.** observed the use of nano-refrigerant in the refrigeration whose occurrence provides the increment in COP. They concluded that COP increases with respect to the increment in capillary tube length and highest COP can be achieved with the efficient capillary tube length [8].

**J.C. kapur et al.** conducted the analysis of using the solar energy and providing the feasibility of the use of solar energy in refrigeration and air conditioning and to obtain a most preferred system in Indian conditions. They work on the various refrigeration systems using vapor compression system of refrigeration which is concluded as the most efficient system of refrigeration when solar energy is used as the source of power [9].

**Maamar Ouali et al.** conducted an analysis regarding the protection of our environment on which all over the world the researchers in a deep concern with the different parameters. They observed that for the protection of our environment energy efficiency is the most powerful tool. They show a focus on reducing the rate of energy consumption of household refrigerators and protect our environment from the CO2 gas emissions. Moreover, with respect to the reduction in energy consumption and the decrease in the capacity of the PV generator and solar batteries, this reduces the cost of PV installation which also termed as the levelized cost of energy analysis. So all study give us a new way for live, move and sustainable work [10].

**Geppert et al.** conducted an analysis on the energy consumption of the different appliances and observed that refrigerators are responsible for a large amount of the total energy consumption in the residential sector. Moreover, due to that the researchers all over the world concentrating on these appliances so that energy consumption will have reduced in an efficient manner. This study gives us valuable information regarding the energy consumption of domestic refrigerator for their sustainable working [11].

**Sarbu et al.** conducted an analysis for providing the solutions for fossil fuels and providing the renewable energy sources which are most available in nature. They focused on providing effort to protect the ozone layer and removal of environment bad effects scientists work on renewable energy resources which are easily available [12].

**Kattakayam et al.** conducted analysis and discovered that there`s no degradation of the performance of refrigerator once operated on not pure sine wave input. Moreover, the energy efficiency of the refrigerator can be improved with the help of this analysis [13].

**Bentouba Said et al.** conducted an analysis regarding the hybrid system and environmental safety and they concern with the help of a case study. They concluded that with the increase in demand for electricity in all over the global, the renewable energy technology looks like having the great opportunity for the fulfillments of those areas requirement. They observed that maximum power demand can be supplied by the hybrid system. They concluded that cost of generating energy is less while considering the comparison with other systems. They concluded that with regard to the technological developments in near future this renewable energy creates more development and opportunities and reduce pollution and works for every system and represent our technology environment friendly in nature [14].

**Maria C. Browne et al.** conducted an analysis to design a photovoltaic system in addition to a thermal collector with regard to solar radiation to generate electricity and provide refrigeration effect. They observed while experimentation the use of phase change material with regard to the thermal system in the concern with the case study. They noticed that with regard to the variations in solar radiation occurrence on a PV module is to be converted into electricity. They also noticed that system presents better thermal efficiency in comparison with other systems [15].

**Alan K. Meier et al.** conducted an analysis regarding to the energy savings observed for different appliances with respect to the improvement in efficiencies of these appliances. They observed the savings from different appliances and interruptions occurred with regard to the verification of the savings [16].

**Aldo Orioli et al.** conducted an analysis for the sustainability of PV technology and its appearance at the global level and its importance regarding economical existence. Besides, their occurrence for providing clean renewable electricity with respect to the other systems. They observe while focusing on the cost analysis with the consideration of an LCOE the electricity generation in high amount photovoltaic technology is investigated [17].

**Tatiani Georgitsioti et al.** conducted an analysis with respect to the changes occur in the supporting structure and observing the cost effectiveness of our photovoltaic systems. They observed during the investigation of the domestic refrigerator with the consideration of case study in which variations in prices and polices are to be there. They observed the variations in LCOE in various cities in while studying the case study. They also observed the principal of negative bias, positive bias with respect to the variations in LCOE and when LCOE value becomes zero which termed as neither profits nor cost of the PV generation system. They observed while considering the economic analysis, in the concept of payback period a zero LCOE presents to recover its investment. They concluded the domestic PV systems can achieve the lowest cost of energy produce during their case study [18].

**Seth B. Darling et al.** conducted an analysis on photovoltaic electricity with regard to the suddenly increased researcher's interest towards the use of renewable energy source and will consider as providing large amount in global energy production. Moreover the analysis of calculating cost of solar generated electricity compared to electricity produced by other systems with a Levelized cost of energy calculation. They used simulation technique for the production of Levelized cost of energy of solar PV system and also focusing on the assumptions during investigation [19].

**K. Branker et al.** conducting an analysis on the sustainability of the solar photovoltaic (PV) system moreover for our PV systems the economic analysis is to be taken in care while observing the feasibility of our system and the term levelized cost of electricity generation define that in an efficient way. They studied the nature of our system while considering the case study and LCOE is to be calculated for the same case. They observe the different assumptions while calculating the LCOE. They concluded that PV system has shown innovation for producing electricity in concern with economic growth while considering the comparison with other refrigeration systems [20].

**Arvind Chel et al.** conducted an investigation on stand-alone photovoltaic power system while considering the concept of sizing and cost analysis. They also consider the effect of sun energy for the efficient working of our system. They concluded that SAPV system is to be a concern with to avoid the difficulty of providing transmission lines and remove large energy losses which are occurred while transmitting of electricity over long distances. They concluded that our system is not to be a concern with a large amount of CO2 gas emissions which in the result of the safety of our environment. They concluded that PV power systems can be taken as the innovation with regards to the global economy and which shows ability in terms of converting the sunlight energy directly to electrical energy having less maintenance cost, negligible noise and environment pollution. [21].

**E.A. Alsema et al.** conducted an analysis on photovoltaic systems for the sustainability of those systems. They observed mainly with respect to the input our photovoltaic system generate sufficient output energy. They observed the reduction of energy consumption in PV system and improved PV system performance and lifetime also affected. They observed that the energy pay back period may be less than for the future PV technology systems. They also focus on the greenhouse gases emissions which are calculated by using our system was lower than the emissions from fossil fuels [22].

**Ghassan Zubi et al**. conducted an analysis on the development of PV systems and in other words for the sustainability of our systems. They concluded that cost reductions are to be provided by our system. They concluded that PV technology provide feasibility to provides electricity to those areas where electricity not available in the renewable form which in terms of economic advantage and environmental safety [23].

**Rita Paleta et al.** conducted an analysis on the development of those areas where electricity not available and in insufficient amount with respect to demand is to be there. They observed the many places in the world and which are having different demands. They observed that isolated energy system which is operated on renewable energy having represented as the most efficient system which presents automatic working conditions when the storage system is to be provided with batteries. They concluded that while considering the comparison with all other systems our hybrid system will have the most technical and cost effective solution. They observe that our system presents the innovation with regard to the economic development of the different countries [24].

**Adnan Sozen et al.** conducted an analysis due to the great efforts of researchers for the safety of our environment from different processes like ozone layer depletion and global warming effect. They noticed that while considering the restriction to different equations artificial neural network presents values to represent the thermodynamic equations. They present the innovative method which is represented as an artificial neural network for the determination of different phases with regard to different refrigerants [25].

**Mitsuhiro Fukuta et al**. conducted analysis with regard to the possibility of a hybrid system which is operated by the pair of a different refrigerant and also recommended energy saving with the consideration of recycling the waste heat. They observed the performance of the hybrid cycle both theoretically and experimentally during their investigation. They observed that our system is to be achieved high efficiency with the consideration of recycling the waste heat [26].

**J.U. Ahamed et al.** conducted an analysis in which they show the feasibility of vapour compression refrigeration system with regard to the concept of exergy analysis. They noticed that while working with vapour compression refrigeration system considering with different refrigerants the main concern is regarding exergy analysis. They noticed that while observing the vapour compression refrigeration system in which compressor having an occurrence of maximum exergy loses. They observed that our system performance will be improved with the consideration of a maximize exergy efficiency and minimize the exergy destructions or losses [27].

**Camelia STANCIU et al.** conducted an analysis to prepare and modal our VCRS for the different refrigerant propositions. They studied different parameters and factors with reference to exergy analysis whose mainly effects on the performance of our system. They concluded that study deals with specific information regarding the efficient system which will have required for different refrigerants [28].

**H.VALIZADEH et al.** conducting an analysis for the sustainability of the solar refrigeration system. They observed that our system can be improved by storing the excess energy during the day time in which sun energy available in the battery system [29].

**B.O. Bolaji et al.** conducted an analysis using refrigerants R152a and R32 for the replacement of R134a in a domestic refrigerator. The refrigerants performance compared with R134a and the coefficient of performance with the use of R152a is more in less time comparing with R134a while COP of R32 is lower compared with R134a.The refrigerator consumes lower energy and shows better performance with the use of R152a [30].

# 5 Equipments, material and experimental setup

The equipments used during our investigation are following: Vapour compression refrigeration system, different refrigerants like R290/R600a/R134a.

The materials which are preferred for our investigation purpose are mix refrigerant with different volumetric proportions which will have worked environment friendly in the refrigerator.

The experimental system consist of most widely used appliance in the world domestic refrigerator whose operated with the use of mixed refrigerant to reduce the emissions of gases. In this the vapour compression refrigeration system is used which was most globally used system and highly efficient system.

## 5.1 Terminology

In this section of terminology, terms of body related to our research work are discussed and shown below:

### 5.1.1 Components of the refrigeration system

Our refrigeration system is having five basic components. From those these four main components are described below:

1. Compressor
2. Condenser
3. Evaporator
4. Expansion devices
5. Refrigerant: to conduct the heat from the product

All these components are defining our refrigeration system for the successful operation of the refrigeration cycle.

#### 5.1.1.1 Compressor

While thinking of different components of our system the important component is the compressor and compressor is shown below in figure 5.1. The function of a compressor is to draw low pressure and low temperature refrigerant vapour from the evaporator at which can boil and extracting heat from the refrigerated space. Once drawn, the refrigerant vapour is compressed. During the refrigerant compressing vapour, pressure and temperature transforms into the high temperature and high pressure refrigerant vapour to a level at which it can condense by rejecting heat to the cooling medium in the condenser.

**Figure 5.1: Compressor**

#### 5.1.1.2 Condenser

Condensers are referring towards phase change of refrigerant and basically heat exchanger. In other words, while caring of proper performance of refrigeration system the main requirements are selection of condensers and proper design and the condenser used in our work is to be shown in figure 5.2. Condenser refers as a sink which rejects heat to an external medium. The refrigerant in the form of a superheated state inlet to the condenser and then de-superheated. After this process, the refrigerant condensed by rejecting heat to an external medium. The refrigerant may leave the condenser as a saturated or a sub-cooled liquid, depending upon the temperature of the external medium and design of the condenser. Generally, while taking care of external medium air or water is chosen because naturally availability.

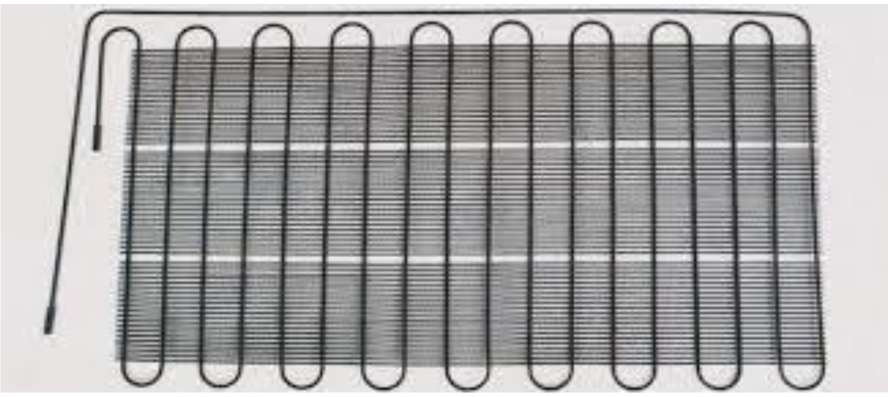

**Figure 5.2: Wire-Tube Serpentine condenser**

#### 5.1.1.3 Evaporator

The evaporator as per condenser also reacts as a heat exchanger. In an evaporator, the refrigerant boils or evaporates and in doing so absorbs heat from the substance being refrigerant. The evaporator used during our research work is shown in figure 5.3.

**Figure 5.3: Roll-Bond Evaporator**

#### 5.1.1.4 Expansion Device

The expansion device provides reduction in pressure from condenser pressure to evaporator pressure and to regulate the refrigerant flow from the high pressure liquid line into the evaporator at a rate equal to the evaporation rate in the evaporator.

#### 5.1.1.5 Capillary tubes

A capillary tube is a tube in the narrow shape having constant diameter having long length. The capillary tube having inner tube diameter in the variation from 0.4mm to 2mm and variation in length from 0.6m to 6m.The capillary tube is to be shown in figure 5.4. The reduce in pressure in a capillary tube occurs due to following factors:

1. Pressure drop due to frictional resistance offered by tube walls.
2. Pressure drop due to acceleration of refrigerant as it flows through capillary.

**Figure 5.4: Capillary Tube Expansion Valve**

## 5.2 Refrigerants

A fluid which is generally used in refrigeration or heat pumps termed as a refrigerant. Refrigerant undergoes phase transitions from liquid to gas in most of the cycles. In the $20^{th}$ century chlorofluorocarbons and fluorocarbons were used and are being ruled out due to their global warming potentials and ozone depletion effects.

- Primary
- Secondary

Primary refrigerants: Primary refrigerants are termed as refrigerants having directly used as fluid in the working form. The examples are like in vapour compression and vapour absorption refrigeration system. The use of primary refrigerants provides the change of phase in evaporator.

Secondary refrigerants: Secondary refrigerants are termed as refrigerants having transportation of energy from one place to another. The use of secondary refrigerants provides no change of phase.

Thermodynamic efficiency depends on operating temperatures.

If the operating temperatures are above 0◦C, then we use secondary type of refrigerants.

If the operating temperature is less than 0◦C then we use the primary type of refrigerants.

### 5.2.1 Refrigerant selection basis

The refrigerant selection for any application is on the basis of following requirements:-

#### 5.2.1.1 Thermodynamic and Thermo-Physical Properties

Suction Pressure: - As reference towards temperature of evaporator, the pressure of saturation is to be higher than the atmospheric for the safety of our system from air or moisture. The suction pressure is taken as good when it is high as provides smaller displacement of compressor.

Discharge Pressure: - As reference to temperature of condenser, the pressure of discharge is to be as small as per possibility.

Pressure ratio = $P_{condenser}$ / $P_{evaporator.}$

The value of Pressure ratio required as small as possible.

Latent Heat of Vaporization: - It should be as large as possible.

#### 5.2.1.2 Thermodynamic properties

- Normal boiling point
- Critical temperature
- Molecular structure

  For most refrigerants

  (Normal boiling point / Critical temperature) = 0.6→0.7

Inorganic refrigerants – $NH_3$

Organic refrigerants –

- Operating molar specific heat is 40-100 KJ/K mol K.

#### 5.2.1.3 Environmental and Safety

While taking care of environment our refrigerant shows the following considerations:

1. ODP (ozone depletion potential):- The value of ozone depletion potential should be zero.
2. GWP (global warming potential):- The value of global warming potential should be zero.
3. Total equivalent warming impact (TEWI):-TEWI provides the measurement of direct and indirect considerations.
4. Toxicity: - Refrigerant should be non- toxic in nature.
5. Flammability:- Refrigerant should be non-flammable.
6. ASHARE:- ASHARE defined as American society of heating, air conditioning, refrigeration engineering)

Refrigerants: A1 A2 A3 → leas hazardous.

B1 B2 B3 → Most hazardous.

A → R11, R12, R134a, R22, R744, R718

B→ R1140.

7. Chemical stability: -Refrigerants showing chemical stability as far as having there occurrence in the system.

8. Compatibility: - It must be necessary.

9. Miscibility: - Mixing property should be fine.

#### 5.2.1.4 Economical

- Refrigerant should be easily available at reasonable cost.

### 5.2.1.5 Nomenclature of refrigerants

As we know large amount of refrigerants are investigated by researcher for different applications area. The numbering system has been developed for designate refrigerants. The example for that is shown below:

R134a:-

R=Refrigerant

1=the number of carbon (C) atoms +1

3=the number of hydrogen (H) atoms -1

4=the number of fluorine (F) atoms

a=lowercase letter denotes specific isomer (molecular formation)

The chemical formula for R134a is $C_2H_2F_4$.

### 5.2.1.6 Binary Mixtures

- Azeotropic mixtures
- Zeotropic mixtures

Azeotropic: - Azeotropic mixture is represented in the 500 series.

R507: mixture of R125 (50%) + R143a (50%)

R502: mixture of R22 (48.8%) + R115 (51.2%)

Zeotropic: - Zeotropic are represented in the 400 series.

R407B: R32 (10%) + R125 (70%) + R134a (20%)

R404a: R125 (44%) + R144a (52%) + R134a (4%)

### 5.2.1.7 Hydrocarbons

- Saturated:

  Propane: $C_3H_8$ (290)

  n- Butane: $C_4\ H_{10}$ (R600)

  Isobutane: $C_4\ H_{10}$ (R600a)

- Unsaturated

  R1150: ($C_2 H_4$)

  R1270: ($C_3 H_6$)

### 5.2.2 Properties of various Refrigerants

The properties of the investigated refrigerants are described in a table 5.1.

| Refrigerant | Properties | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Critical Pressure | Critical Temperature | Gas Density | GWP | Liquid Density | Molecular Mass | NBP | ODP |
| Unit | Bar | K | $Kg/m^3$ | | $Kg/m^3$ | g/mol | K | |
| R1234yf | 33.82 | 367.7 | 4.77 | 4 | 1100 | 114 | 243.51 | 0 |
| R1234ze | 36.36 | 382.36 | 4.77 | 7 | 1252.9 | 114 | 254.03 | 0 |
| R134a | 40.59 | 374.21 | 14.35 | 1430 | 1295.2 | 102 | 247.08 | 0 |
| R12 | 41.36 | 384.97 | 5.22 | 10900 | 1490 | 120.9 | 243.2 | 1 |
| R450A | 38.14 | 379.02 | 13.93 | 547 | 1253.2 | 75 | 251.2 | 0 |
| R152a | 47.6 | 387 | 2.76 | 124 | 2700 | 66.05 | 248.98 | 0 |
| R22 | 49.9 | 369.1 | 3.5 | 1600 | 1262.7 | 86.48 | 232.2 | .055 |
| R290 | 42.5 | 369.7 | 4.8 | 3 | 500.1 | 44 | 231 | 0 |
| R600a | 36.4 | 407.7 | 8.76 | 10 | 556.9 | 58.1 | 261 | 0 |
| R32 | 53.8 | 351.4 | 2.15 | 675 | 1100 | 52.02 | 221.35 | 0 |
| R417A | 40.3 | 360 | 2.46 | 1950 | 1230 | 81.6 | 233.9 | 0 |
| R436A | 41.7 | 389.05 | 2.89 | 10 | 1207 | 84 | 228.6 | 0 |

**Table 5.1: Investigated properties of different refrigerants**

### 5.2.3 Mixed refrigerants

The mixed refrigerants and newer substances which are developed now a day to remove the bad effects of previously used substances. So, taking care of our refrigeration system, as we know the degrading effects of chlorofluorocarbons and fluorocarbons. Moreover, there is a requirement of new refrigerant to reduce these effects. Now with the use of mixed refrigerant, we obtained higher COP with lower consumption of power. The properties of refrigerants used in our research shown below in tables 5.2, 5.3, 5.4.

| | |
|---|---|
| Formula | $CH_3$-$CH_2$-$CH_3$ |
| Family | Hydrocarbons |
| Main application | Heat pumps |
| Normal boiling point (at 0.1013 Mpa) | -42.1$^0$C |
| $C_p$ | 2.506 |
| Critical temperature | 96.7$^0$C |
| Critical pressure | 4.25Mpa |
| ODP | 0 |
| Molar mass | 41.1kg/k mol |
| GWP | 20 |

**Table 5.2: Properties of R290**

| | |
|---|---|
| Formula | $CH(CH_3)_2$-$CH_3$ |
| Family | Hydrocarbons |
| Molar mass | 58.1kg/k mol |
| Normal boiling point (at 0.1013 Mpa) | -11.6$^0$C |
| $C_p$ | 2.306 |
| Critical temperature | 134.7$^0$C |
| Critical pressure | 3.64Mpa |
| ODP | 0 |
| Main application | Domestic Refrigerator |
| GWP | 20 |

**Table 5.3: Properties of R600a**

| | |
|---|---|
| Formula | $C_2H_2F_4$ |
| Family | HFC |
| Molar mass | 102.03 g/mol |
| Normal boiling point (at 0.1013 Mpa) | -26.1$^0$C |
| Cp | 0.0875 |
| Critical temperature | 100.95$^0$C |
| Critical pressure | 40.6 bar |
| ODP | 0 |
| Main application | Domestic refrigerator |
| GWP | 1200 |

**Table 5.4: Properties of R134a**

## 5.3 Charging of Refrigerants

After the whole setup prepared, now the time to charge the refrigerator with the use of different proportions of selected refrigerants. Moreover, before the charging of a refrigerator, firstly our system should be evict and removing air, gas and other impurities so that to effect the working of refrigerator with the new working refrigerant. These all considerations are provided by using the vacuum pump at the expansion valve. After this work, the valve of the refrigerant cylinder is to be connecting to the compressor at the suction end with the help of dual pressure gauges. Besides, the refrigerator starts and the refrigerant distributes into the condenser, evaporator. The refrigerant after inlet to the compressor it should get vaporized to protect the compressor from over flooding and in other terms this results in increment in efficiency.

Now the important thing which must be in mind the refrigerant with low pressure should be charged in first short which provides the mixing of refrigerants properly. During the charging of mixed refrigerant the readings of densities and pressures of refrigerants must note down. During our experiment, R600a, R290 and R134a have pressures of 36.4bar, 42.5bar and 40.59 bar so we charged R600a first then R134a and simultaneously the R290.

## 5.4 Pressure Gauges and Thermocouples

### 5.4.1 Thermocouples

Thermocouple is the temperature measuring device which termed as sensor. These are having two wires which are of different metals. These wires forms one end with the help of welding. Where these wires are welded having termed as temperature measuring source. So, this station when observe the change in temperature which termed as formation of voltage.

DS18B20 thermocouple which provides the measurement of temperature.DS18B20 having Technical specifications

- It provides temperature measurement from -55 to $125^0$C
- Its resolution is from 9 to 12 bits which selectable by user
- It requires only one digital pin for communication
- $0.5^0$C accuracy from $-10^0$C to $+85^0$C
- It can be used with 3.0V to 5.5V power.

### 5.4.2. Pressure Gauges

Pressure gauges provide measurement of pressure in the liquid or gas form during the saturated state. The measurement of pressure is in the in units like $N/cm^2$, Psi, bar, atm. The diagram for pressure gauge is to be shown is figure 5.5.


**Figure 5.5: Pressure gauge**

# 6 Research Methodology

In our research, we run our refrigerator using the mixture of refrigerants in different proportions having refrigerants R600a, R290 and R134a.Firstly, data was analyze and reviewed with the help of multiple information sources like from research papers and Internet search engines. After getting the all information we have concluded our research basis when we know that blends of refrigerants provides higher COP while comparing with single refrigerant.

Moreover, we have gathering data from surveying online and collected the list of various companies whose provides equipments of refrigeration system which match our specification that are required.

After the gathering of all equipments, we assembled the following equipment wire and tube serpentine condenser (0.301 square meters), roll bond evaporator (0.3535 meter square), capillary tube expansion valve and hematic reciprocating compressor (410BTU/hr).

Hence the system is new, our equipment having charge less now and without any charge. Now, we will connect the suction valve of compressor with the charging valve with the help of a dual sided pressure gauge and other sided to refrigerant tank. So, after the filling of charge in our system pressure formed in the compressor is low and in other way refrigerant is to be sucked from the container into the compressor and its outlet is connected to condenser.

After these all, the observance of pressure in the pressure gauge is to be there and we calculate the refrigerant in how much amount sucked by the compressor.

By the above process, we have charged the refrigerant and the sequence in which we charged in given below and represented in the table 6.1.

The temperature sensor which we used DS18B20, has a property called one wire bus. We have used a total sensor and placed them near inlet and outlet of compressor, outlet of Condenser and in Evaporator.

| Case | R290 (%) Composition | R600a (%) Composition | R134a (%) Composition |
|---|---|---|---|
| 1 | 40 | 20 | 40 |
| 2 | 40 | 40 | 20 |
| 3 | 20 | 40 | 40 |
| 4 | 32 | 36 | 32 |
| 5 | 40 | 28 | 32 |

**Table 6.1: Mixed refrigerant showing composition proportions**

First we will bring the evaporator to room temperature and will rem the refrigeration rig and until the temperature is shown by DAQ will finally become stable. Then we stop running the rig and gas empty the charge present in the system by releasing the valve in the pressure gauge, letting the refrigerants into the atmosphere after it is empty, we will charge it again. Then we have compared all the values and measured the COP and other reading and have found out the experimental results.

The experimental setup for the domestic refrigeration system is to be shown in figure 6.1 and with the use of this our all experiment work was covered for the investigation.

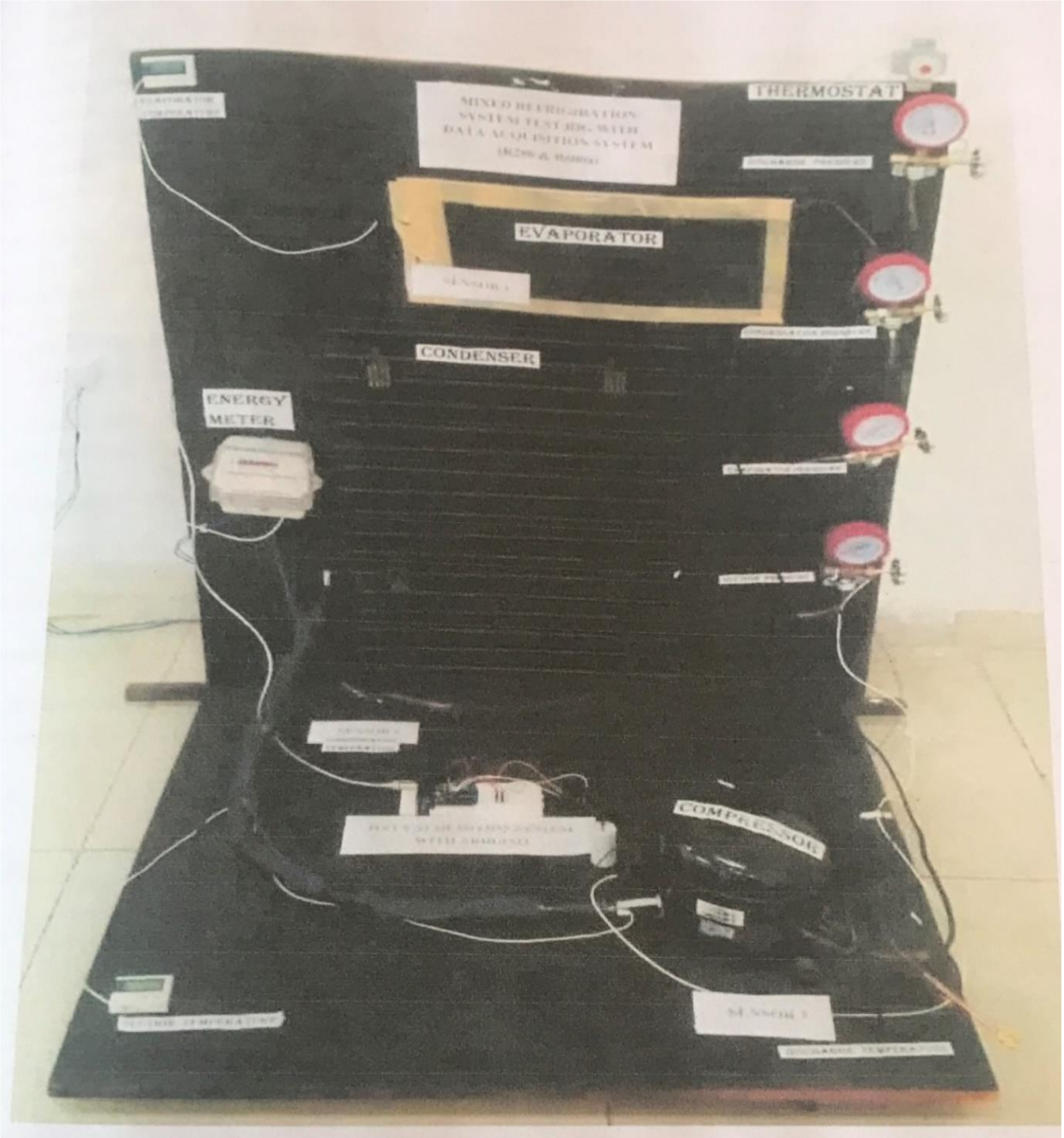


**Figure 6.1: Refrigerator System**

## 7 Proposed work plan with timelines

The proposed work plan regarding our investigation in the coming months is represented below with the help of Table 7.1 and figure 7.1.

| Tasks | Start Time | Days to complete |
|---|---|---|
| Prepare experimental setup | 8-Jan | 24 |
| Prepare all material requirements | 2-Feb | 40 |
| Testing | 15-Mar | 40 |
| Prepare report | 28-Apr | 35 |

**Table 7.1: Shows the proposed work plan with timelines**

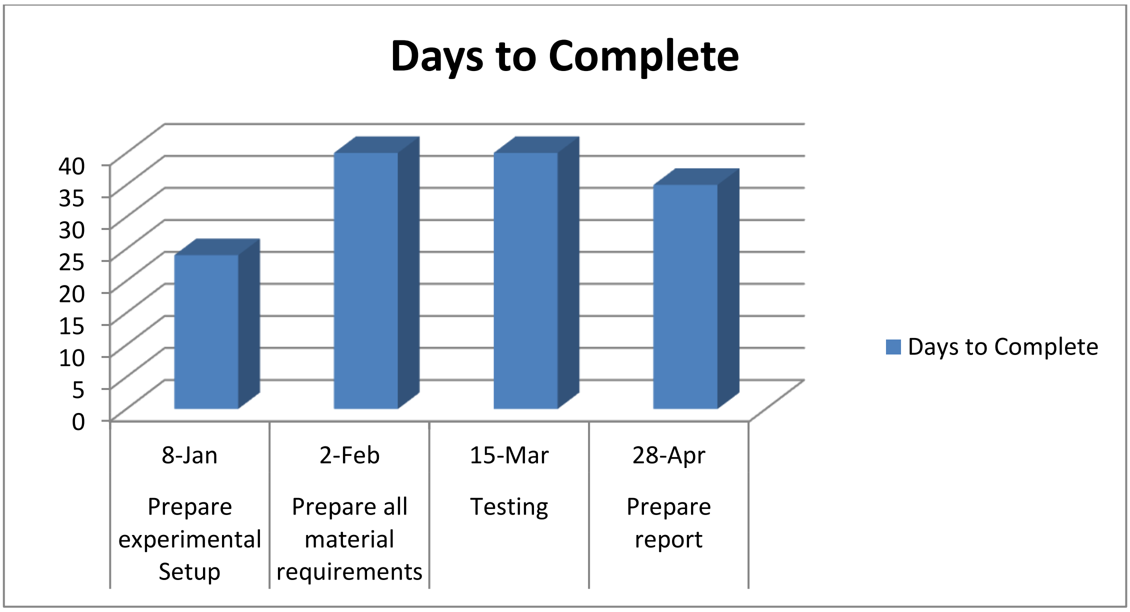


**Figure 7.1: Proposed work plan**

# 8 Experimental Work

The experimental work is to be performed with the help of an experimental setup, refrigerants at different volumetric proportions. The results obtained from the analysis of different iterations work with the use of mixed refrigerants (R290/R600a/R134a) having different proportions is to be represented in the table 8.1

| R290 | R600a | R134a | $P_1$(bar) | $T_1$($^0$C) | $P_2$ | $T_2$ | $P_3$ | $T_3$ | $P_4$ | $T_4$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 20 | 40 | 0.68 | 15.3 | 15.15 | 46.13 | 15.52 | 32.66 | 0.68 | -10.6 |
| 40 | 40 | 20 | 1.37 | 15.1 | 17.91 | 47.34 | 18.61 | 34.31 | 3.44 | -6.7 |
| 20 | 40 | 40 | 0.68 | 15.5 | 15.15 | 51.72 | 15.83 | 29.34 | 1.03 | -7.1 |
| 32 | 36 | 32 | 1.37 | 14.9 | 17.56 | 53.21 | 17.97 | 31.63 | 2.75 | -9.4 |
| 40 | 28 | 32 | 1.24 | 13.6 | 16.53 | 53.31 | 17.22 | 33.41 | 2.06 | -11.4 |

**Table 8.1: Experimental Data**

Where, $P_1$= Pressure at compressor

$T_1$= Temperature at compressor

$P_2$= Pressure at condenser

$T_2$= Temperature at condenser

$P_3$= Pressure at expansion valve

$T_3$= Temperature at expansion valve

$P_4$=Pressure at evaporator

$T_4$= Temperature at evaporator.

# 9 Results and Discussions

In this calculation we measured the COP of a refrigeration system with the use of an experimental method and theoretical method. Coefficient of performance is the measure of the performance of the refrigeration cycle. It is represented with COP and it is defined as ratio of desired output to the work input. In refrigeration cycle the desired output is the cooling temperature we achieve in the evaporator and the work input which is in the form of electrical energy. Its value is always greater than 1 because the heat rejected to the hot sink is greater than the heat absorbed from the cold source.

**Calculation of COP (Coefficient of Performance):-** COP = desired output / work input

COP for case 1 having proportions 40/20/40

$$COP = \frac{T_4}{T_2 - T_4} = \frac{262.4}{319.1 - 262.4} = 4.62$$

COP for case 2 having proportions 40/40/20

$$COP = \frac{266.3}{320.3 - 266.3} = 4.93$$

COP for case 3 having proportions 20/40/40

$$COP = \frac{265.9}{324.7 - 265.9} = 4.52$$

COP for case 4 having proportions 32/36/32

$$COP = \frac{263.6}{326.2 - 263.6} = 4.21$$

COP for case 5 having proportions 40/28/32

$$COP = \frac{261.6}{326.3 - 261.6} = 4.04$$

| $M_1$ | $M_2$ | $M_3$ | COP |
|---|---|---|---|
| 40 | 20 | 40 | 4.62 |
| 40 | 40 | 20 | 4.93 |
| 20 | 40 | 40 | 4.52 |
| 32 | 36 | 32 | 4.21 |
| 40 | 28 | 32 | 4.04 |

**Table 9.1: Investigated COP for different refrigerants proportions**

After the calculation and experimental work it can be seen that the coefficient of performance of R290/R600a/R134a blend in proportions 40/40/20 shows highest value. So the conclusion is that this mixture will be the best choice as per our research. The temperature vs time graph for evaporator of refrigerant mixture R290/R600a/R134a having proportions 40/40/20 is to be shown in figure 9.1.

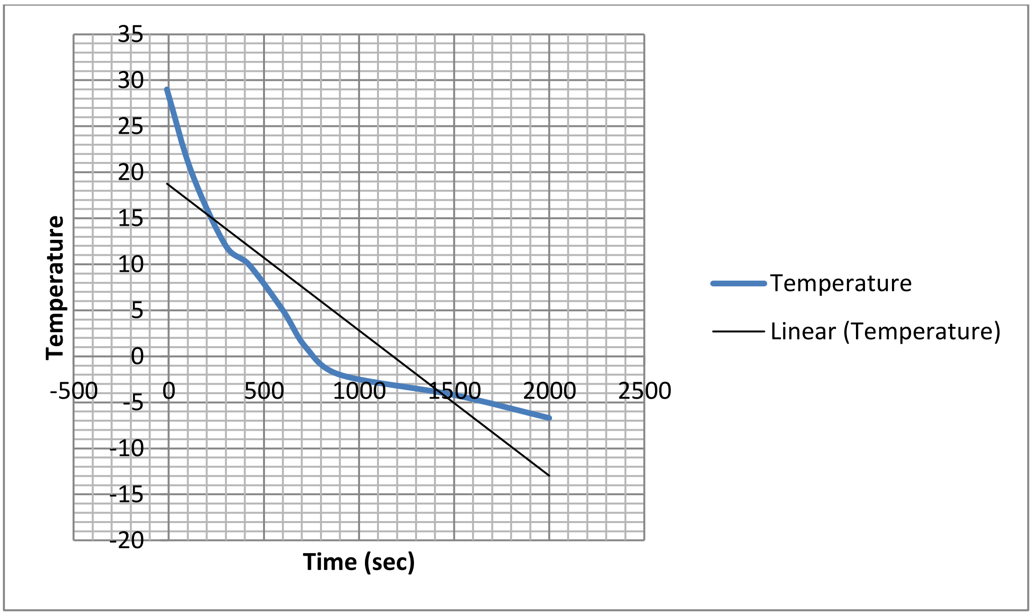


**Figure 9.1: Temperature vs time Graph for Evaporator having composition 40/40/20**

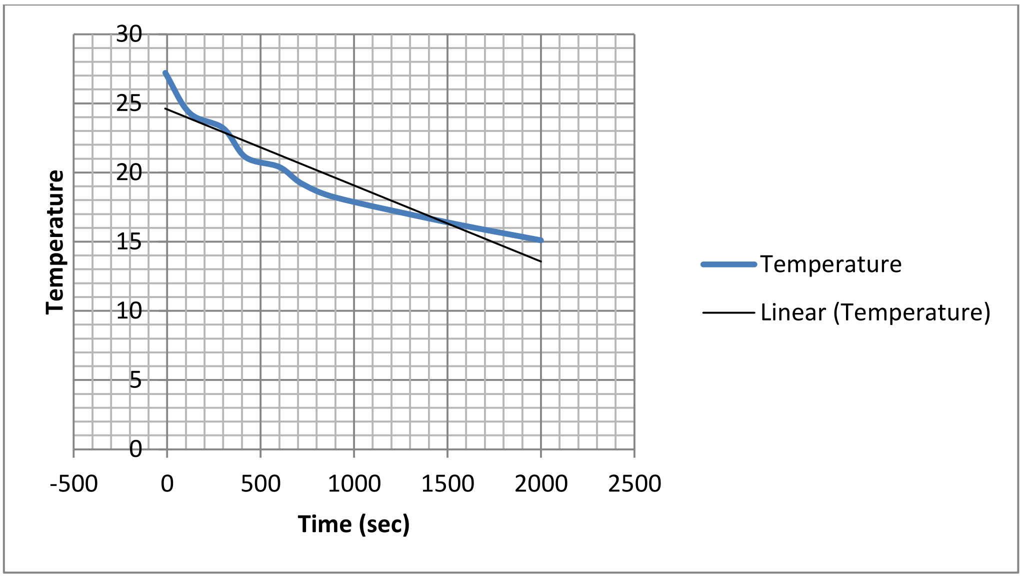


**Figure 9.2: Temperature vs time Graph for Compressor having composition 40/40/20**

The temperature vs time graph for compressor of refrigerant mixture R290/R600a/R134a having proportion 40/40/20 is to be shown in figure 9.2.

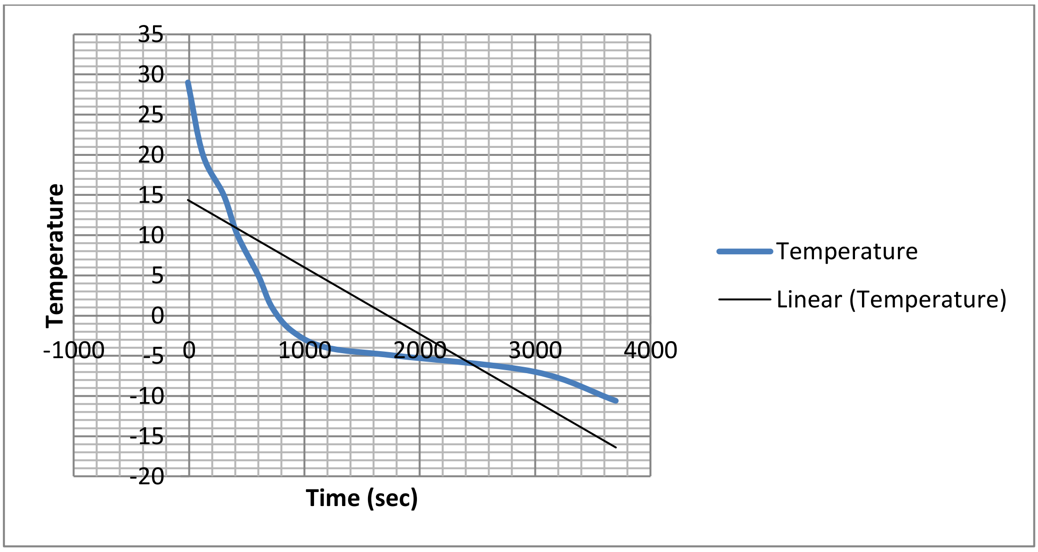


**Figure 9.3: Temperature vs time Graph for Evaporator having composition 40/20/40**

The temperature vs time diagram for evaporator of refrigerant mixture R290/R600a/R134a having volumetric proportion 40/20/40 is to be shown in figure 9.3 and evaporator is to be attained the temperature of -10.6 after working for near about 3800 seconds and at their stable temperature conditions is to be obtained.

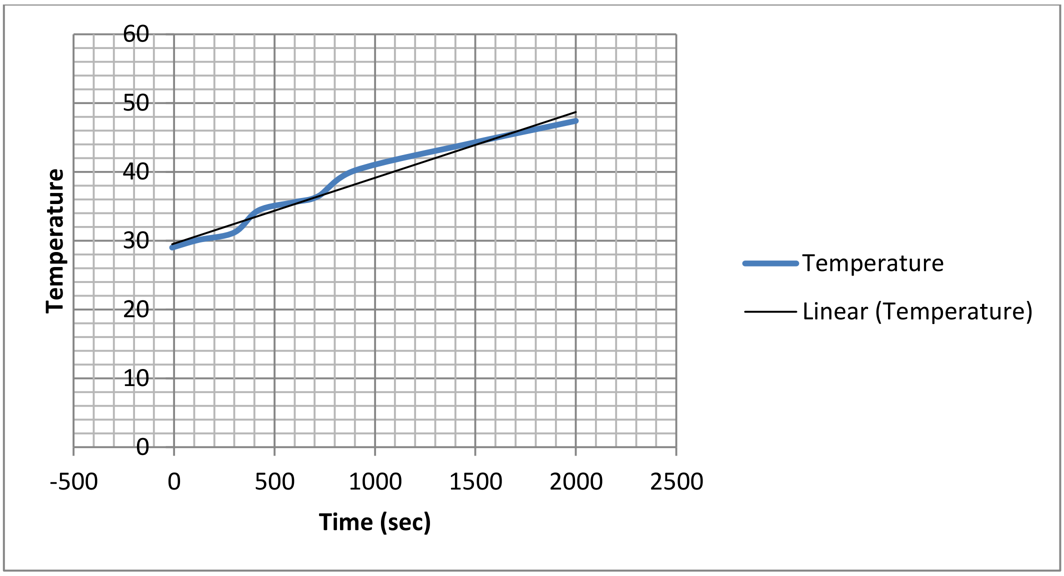


**Figure 9.4: Temperature vs time Graph for Condenser having composition 40/40/20**

The temperature vs time graph for condenser of refrigerant mixture R290/R600a/R134a having volumetric proportion 40/40/20 is to be shown is figure 9.4 and temperature of 47.34 is to be attained after working for 2000 seconds and at their stable temperature is to be obtained.

**Analytical Method:**

**Case-1 (R290/600a/134a- 40/20/40)**

| R290 | R600a | R134a |
|---|---|---|
| $h_1$=$h_g$=590.47 kJ/kg at $T_1$ | $h_1$=$h_g$=574.13 kJ/kg | $h_1$=$h_g$=276.46 kJ/kg |

$$h_{1ef} = \frac{590.47*40+574.13*20+276.46*40}{40+20+40} = 461.59$$

$$\mathbf{h_2=h_{2`}+c_p\,(T_2-T_{2`})}$$

At $T_2$, $T_{2}^{`}$ =$T_3$

| | | |
|---|---|---|
| $h_2$=618.86+3.02(46.1-32.66) =659.44 kJ/kg | $h_2$=615.71+2.58(46.1-32.66) =650.51 kJ/kg | $h_2$=431.24+1.03(46.1-32.66) =445.11 |

$$h_{2ef} = \frac{40*659.44+20*650.51+40*445.11}{100} = 571.92$$

At $T_{3,}$

$$\mathbf{h_3=h_4=h_{3r}}$$

| | | |
|---|---|---|
| $h_4$=286.13 kJ/kg | $h_4$=277.88 kJ/kg | $h_4$=193.21 kJ/kg |

$$h_{4ef} = \frac{40*290.72+40*281.91+20*273.91}{100} = 283.83$$

$$COP_{th} = \frac{461.59-247.31}{571.92-461.59} = 1.942$$

**Case-2 (R290/R600a/R134a-40/40/20)**

| **R290** | **R600a** | **R134a** |
|---|---|---|
| $h_1$=$h_g$= 590.02 kJ/kg at $T_1$ | $h_1$=$h_g$=574.13 kJ/kg | $h_1$=276.4 kJ/kg |

$$h_{1ef} = \frac{40*590.02+40*574.13+20*276.4}{40+40+20} = 520.96 \text{ kJ/kg}$$

$T_2$, $T_2$`=$T_3$

| | | |
|---|---|---|
| $H_2$=619.2+3.02(47.3-34.31)<br>=658.24 kJ/kg | $H_2$=617.31+2.58(47.3-34.31)<br>=650.91 kJ/kg | $H_2$=444.23+.88(47.3-34.31)<br>=455.77 kJ/kg |

$$h_{2ef} = \frac{40*658.24+40*650.91+455.77*20}{100} = 614.81 \text{ kJ/kg}$$

At $T_3$,

**$h_3$=$h_4$=$h_{3r}$**

| | | |
|---|---|---|
| $h_4$=290.72 kJ/kg | $h_4$=281.91 kJ/kg | $h_4$=272.91 kJ/kg |

$$h_{4ef} = \frac{40*290.72+40*281.91+20*273.91}{100} = 283.83 \text{kJ/kg}$$

$$COP_{th} = \frac{h_{1ef}-h_{4ef}}{h_{2ef}-h_{1ef}} = \frac{520.96-283.83}{614.81-520.96} = 2.53$$

**Case-3 (R290/R600a/R134a-20/40/40)**

| **R290** | **R600a** | **R134a** |
|---|---|---|
| $h_1$=$h_g$=593.21 kJ/kg | $h_1$=$h_g$=575.11 kJ/kg | $h_1$=277.11 kJ/kg |

$$h_{1ef} = \frac{20*593.21+40*575.11+40*277.11}{20+40+40} = 459.53$$

**$h_2$=$h_{2`}$+$c_p$ ($T_2$-$T_{2`}$)**

At $T_2$, $T_{2`}$=$T_3$

| | | |
|---|---|---|
| $h_2$=622.21+3.12(51.7-29.34) =692.06 kJ/kg | $h_2$=621.88+2.62(51.7-29.34) =679.32 kJ/kg | $h_2$=447.21+0.89(51.7-29.34) =467.16 kJ/kg |

$$h_{2ef} = \frac{20*692.06+40*679.32+40*467.16}{100} = 597$$

At $T_3$,

| | | |
|---|---|---|
| $h_4$=278.11 kJ/kg | $h_4$=270.34 kJ/kg | $h_4$=184.34 kJ/kg |

$$h_{4ef} = \frac{20*278.11+40*270.34+40*184.34}{100} = 237.49$$

$$COP_{th} = \frac{459.53-237.49}{597-459.53} = 1.61$$

**Case-4 (R290/R600a/R134a-32/36/32)**

| **R290** | **R600a** | **R134a** |
|---|---|---|
| $h_1$=490.33 kJ/kg | $h_1$=574.11 kJ/kg | $h_1$=276.13 kJ/kg |

$$h_{1ef} = \frac{32*490.33+36*574.11+32*276.13}{100} = 451.94 kJ/kg$$

$$\mathbf{H_2=h_{2`}+c_p\,(T_2-T_{2`})}$$

At $T_2$=$T_{2`}$=$T_3$

| | | |
|---|---|---|
| $h_2$=623.13+3.12(53.2-31.63) =690.42 kJ/kg | $h_2$=624.13+2.64(53.2-31.63) =681.07 kJ/kg | $h_2$=435.21+1.03(53.2-31.63) =457.42 kJ/kg |

$$h_{2ef} = \frac{32*690.42+36*681.07+32*457.42}{100} = 612.49 kj/kg$$

| | | |
|---|---|---|
| $h_4$=283.13 kJ/kg | $h_4$=275.87 kJ/kg | $h_4$=187.11 kJ/kg |

$$h_{4ef} = \frac{32*283.13+36*275.87+32*187.11}{100} = 249.79 kJ/kg$$

$$COP_{th} = \frac{451.94-249.79}{612.49-451.94} = 1.25$$

**Case-5 (R290/R600a/R134a-40/28/32)**

| **R290** | **R600a** | **R134a** |
|---|---|---|
| $h_1$=588.11 kJ/kg | $h_1$=572.33 kJ/kg | $h_1$=274.15 kJ/kg |

$$h_{1ef} = \frac{40*588.11+28*572.38+32*274.15}{100} = 483.24 kJ/kg$$

**$h_2$=$h_{2`}$+$c_p$ ($T_2$-$T_{2`}$)**

At $T_2$, $T_{2`}$=$T_3$

| | | |
|---|---|---|
| $h_2$=623.11+3.12(53.3-33.41) =683.6 | $h_2$=622.87+2.64(53.3-33.4) =675.4 | $h_2$=436.21+1.02(53.3-33.4) =456.66 |

$$h_{2ef} = \frac{40*683.6+28*675.4+32*456.66}{100} = 608.68 kJ/kg$$

| | | |
|---|---|---|
| $h_4$=286.61 kJ/kg | $h_4$=598.11 kJ/kg | $h_4$=192.33 kJ/kg |

$$h_{4ef} = \frac{40*286.61+28*598.11+32*192.33}{100} = 343.66 kJ/kg$$

$$COP_{th} = \frac{483.23-343.66}{608.68-483.23} = 1.11$$

## 9.1 Comparison of Results:

| M($R_1$) | M($R_2$) | M($R_3$) | $COP_{theoritical}$ | $COP_{experimental}$ |
|---|---|---|---|---|
| 40 | 20 | 40 | 1.94 | 4.62 |
| 40 | 40 | 20 | 2.53 | 4.93 |
| 20 | 40 | 40 | 1.62 | 4.52 |
| 32 | 36 | 32 | 1.25 | 4.21 |
| 40 | 28 | 32 | 1.11 | 4.04 |

**Table9.2: Investigated Results**

After the investigated results obtained from the experimental and theoretical calculations we can observe that the coefficient of performance of R290/R600a/R134a mixture is high in 40/40/20 mass proportions in both of the cases. Moreover, with the use of R290/R600a/R134a having mixture of proportions 40/40/20 is the best choice as per our research.

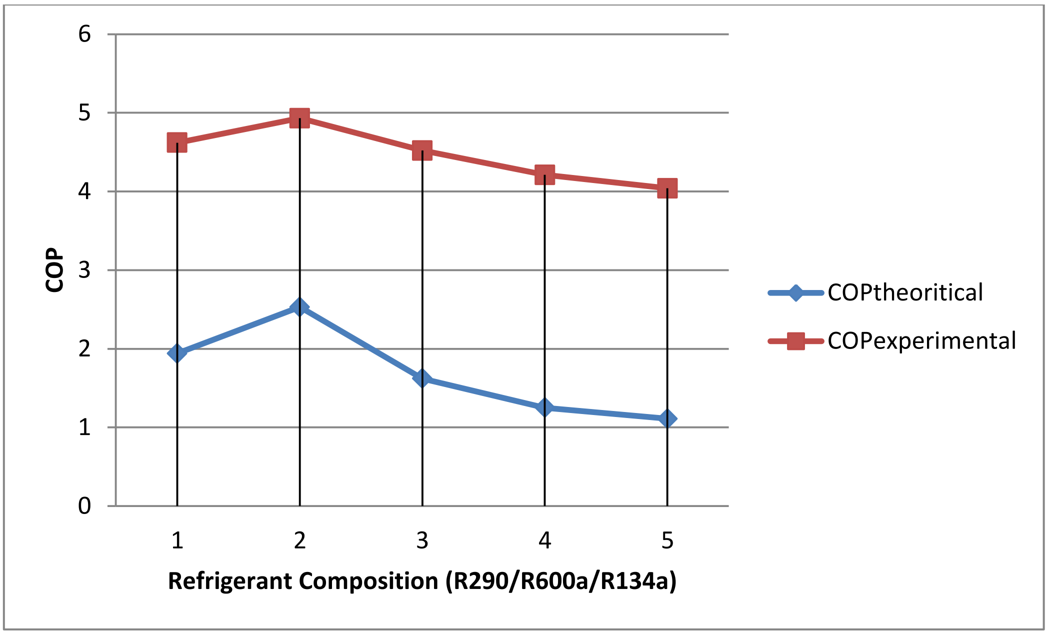


**Figure 9.5: Comparison graph of investigated COP for different refrigerant proportions**

| M ($R_1$) | M($R_2$) | M ($R_3$) | Refrigeration Effect | Compressor work |
|---|---|---|---|---|
| 40 | 20 | 40 | 214.28 | 110.33 |
| 40 | 40 | 20 | 237.13 | 93.85 |
| 20 | 40 | 40 | 222.04 | 137.47 |
| 32 | 36 | 32 | 202.15 | 160.55 |
| 40 | 28 | 32 | 139.57 | 125.45 |

**Table 9.3: Refrigeration effect and Power consumption**

As the results obtained from the calculations of refrigeration effect and power consumption is better in mixture of R290/R600a/R134a having mixture proportions 40/40/20. The graph for different volumetric proportions is to be represented with the help of a figure 9.6.

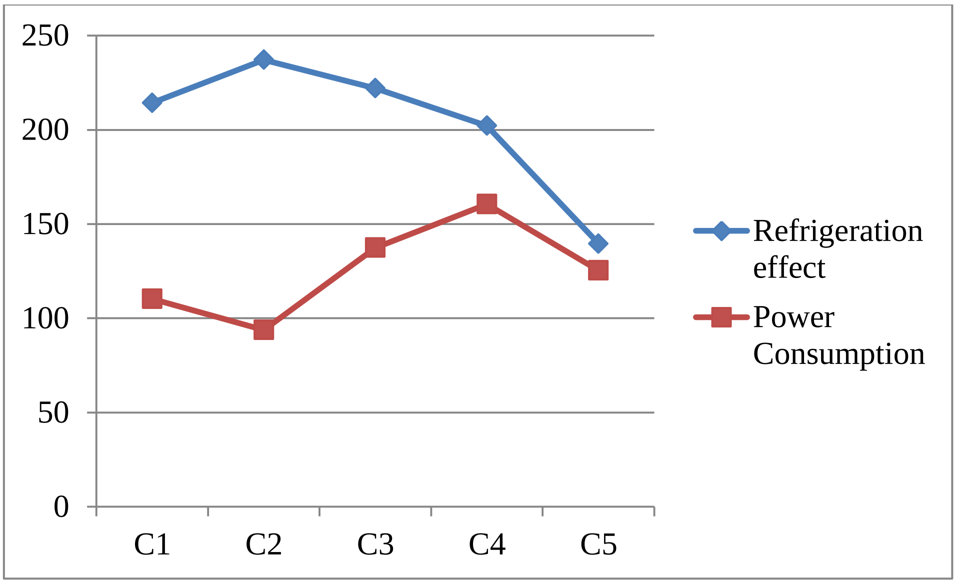


**Figure 9.6: Refrigeration effect and power consumption for different proportions**

# 10 Expected outcomes

The expected outcomes from our refrigeration system are following:-

- Our system provides desire refrigeration effect.
- Our system provides better C.O.P.
- Our system provides reduction in power consumption.
- Our system provides best alternative and environment friendly refrigerants.

# 11 Conclusions

As we concluded, with the reference of mixed refrigerants in our domestic refrigerator result in obtaining lower refrigeration temperature in lesser time. The variations in performance of the refrigerator occurred with the change in refrigerant volumetric proportions. Moreover, our blend of refrigerants R290/R600a/R134a having proportions 40/40/20 shows better coefficient of performance, refrigeration effect and lower power consumption. So, the mixture of refrigerants R290/R600/R134a shows usable volumetric proportions in domestic refrigerator system.

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