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# An experimental study to convert a domestic refrigerator to produce cold water using R134a as a working fluid

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# دراسة تجريبية لتحويل ثلاجة منزلية لإنتاج الماء البارد باستخدام *R134a* كسائل تشغيل

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**Abstract:**
This study designed and constructed a simple vapor compression refrigeration system using R134a as the working fluid. The system's objective was to produce chilled water by immersing an evaporator coil into a water tank. The experiment was conducted under normal atmospheric conditions in a laboratory at the Faculty of Mechanical Engineering Technology in Benghazi, Libya. System performance was monitored by measuring pressure and temperature at the inlets and outlets of the primary components. The enthalpy changes of R134a were calculated to analyze its phase changes throughout the cycle, which were plotted on a P-h diagram. The Coefficient of Performance (COP) was determined for multiple experimental runs. The maximum recorded COP for the system was 2.4.

**Keywords:** Vapor compression refrigeration, R134a, Coefficient of Performance (COP), Enthalpy change, Experimental analysis.

**الملخص**
صممت هذه الدراسة وبنت نظام تبريد بسيط بضغط البخار باستخدام R134a كمائع تشغيل. كان الهدف من النظام إنتاج ماء مبرد بغمر ملف مبخر في خزان ماء. أُجريت التجربة في ظروف جوية عادية في مختبر بكلية تكنولوجيا الهندسة الميكانيكية في بنغازي، ليبيا. رُصد أداء النظام بقياس الضغط ودرجة الحرارة عند مداخل ومخارج المكونات الأساسية. حُسبت تغيرات المحتوى الحراري لـ R134aلتحليل تغيرات طوره طوال الدورة، والتي رُسمت على مخطط P-h. حُدد معامل الأداء (COP) لعدة تجارب تجريبية. كان أقصى معامل أداء مُسجل للنظام 2.4.

**الكلمات المفتاحية:** التبريد بضغط البخار، R134a، معامل الأداء(COP) ، تغير المحتوى الحراري، التحليل التجريبي.

## Introduction

A refrigerant is a working fluid that absorbs heat at a low temperature and pressure by evaporating, and releases it at a higher temperature and pressure by condensing, thereby producing a useful cooling effect [1, 2]. The evolution of refrigerants over the past 150 years reflects a continuous effort to balance efficiency, safety, and environmental impact.

The earliest refrigerants, such as ammonia ($NH_3$), were often hazardous; despite its toxicity, ammonia remains in use today in industrial applications like food processing due to its excellent thermodynamic properties. Carbon dioxide ($CO_2$) was also used early on, though its high operating pressures presented engineering challenges. Hydrocarbons (HCs), initially abandoned in the early 20th century due to flammability, have recently been reintroduced successfully in small, sealed systems like domestic refrigerators.

The 1920s saw a major advancement with the discovery of Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs). These synthetic compounds were non-toxic, non-flammable, and possessed superior thermodynamic properties, leading to their dominance for nearly seventy years. This changed with the Montreal Protocol, which restricted their production due to their destructive impact on the ozone layer, measured by Ozone Depletion Potential (ODP).

CFCs were largely replaced by Hydrofluorocarbons (HFCs), which have zero ODP. However, over the past two decades, the Kyoto Protocol has targeted HFCs for their high Global Warming Potential (GWP). This has spurred the development of a new generation of refrigerants, Hydrofluoroolefins (HFOs), which have very low GWP and are emerging as a leading alternative to HFCs in many applications [3].

### 1.1 Blends and mixtures

Mixing different refrigerants results in blends or mixtures, as an alternative to conventional refrigerants. The mixtures are divided into three categories as follows [3, 4].

- Azeotrope refrigerants: consisted of more than refrigerant that have the same boiling points, for example, R500, R502, R503, and R507.
- Zeotrope refrigerants: consisted of more than refrigerant that have different boiling points, for example R404a, and R407c.
- Near azeotrope refrigerants: consisted of more than refrigerant that has different boiling points, for example R410a. [4].

### 1.2 The optimal properties of refrigerants

- The suction pressure should be higher than the atmospheric pressure to facilitate detection of leakage and to prevent substances from entering the refrigeration system.
- The ratio of compression should be low to reduce the power consumed.
- For a large refrigeration effect, the latent heat of vaporization should be high or the mass flow rate should be small.
- During compression operations, the increase in temperature should be moderate to prevent the chemical reactions between refrigerants, lubricant oils, and other materials which causes the overheating of the compressor.
- The specific heat capacity of the liquid phase should be low; however, the specific heat of the vapor phase should be high [5].
- The thermal conductivity of both the liquid and vapor phases should be high to enhance heat transfer.
- The viscosity of both the vapor and liquid phases should be low [3].

### 1.3 The considerations of refrigerants for vapor compression cycles:

- The heat of vaporization should be high.
- High density of the gas phase.
- Safe, including noncorrosive, nontoxic and nonflammable.
- It has chemical stability under operating conditions.
- Suitable with the materials and compressor oil of the refrigeration system [6,7].
- Suitable working pressure not too high and not below atmospheric pressure.
- Cheap.
- Ease detection of leaks [6].
- Low environmental effects [6, 7].

No refrigerant that meets all requirements; each one may have some undesirable properties Currently most of research focuses on mixing different types of refrigerants to reduce the effect of undesirable properties and improve the properties of refrigerants as a working fluid [8].

### 1.4 Refrigeration system

In 1859 Frenchman Ferdinand Carre invented a first version of the ‘aqua ammonia’ for production continuous cooling. In 1875, refrigeration systems that operate with ammonia appeared, and since that time, refrigeration technologies have developed rapidly, which has positively affected on human life. The classification of the refrigeration systems is presented in Figure 1.

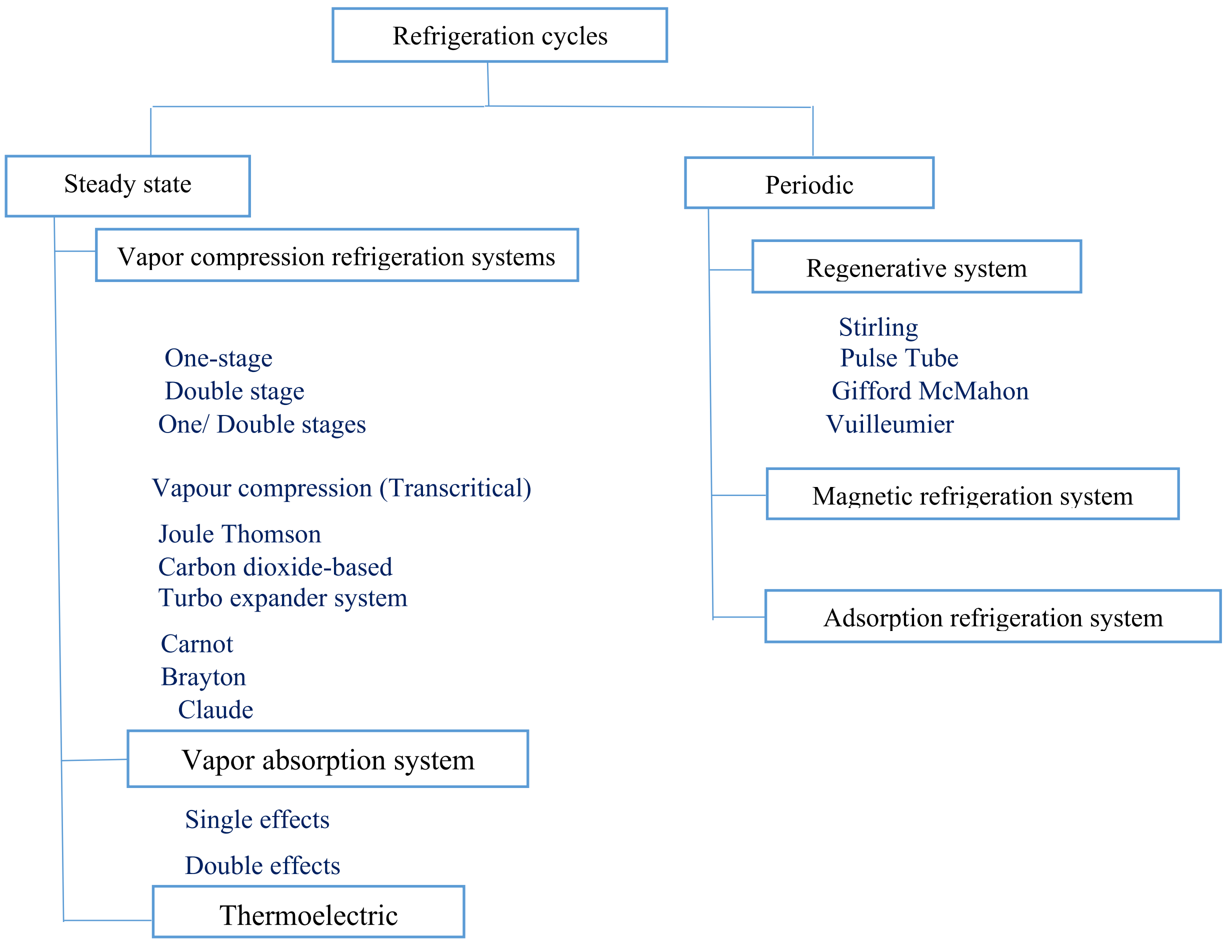



**Figure 1**. Classification of refrigeration methods [3, 7].

**1.5 Vapor compression refrigeration system**

The first machine to produce the cooling process was used in England in 1834. When electricity was available, the development of a refrigeration system began in 1897 [1]. The concept of refrigeration techniques is based on heat rejected to the surroundings at higher temperatures and absorbed it at low temperatures [9] Simple vapor compression refrigeration system as shown in Figure.2 [10].

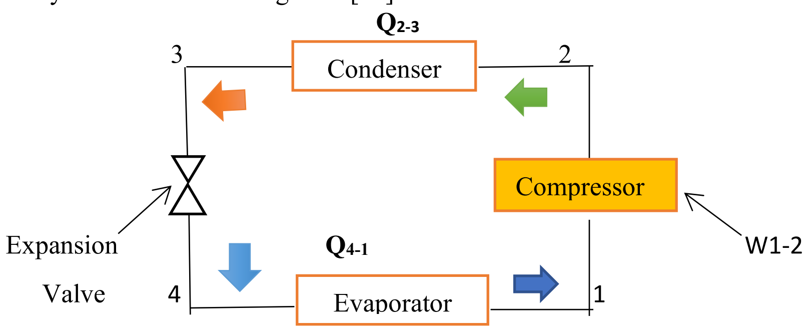



**Figure 2.** Simple vapor compression refrigeration system [3].

Many applications use a VCRS: such as domestic and industrial refrigeration, air conditioners, automobile air conditioners, water chillers, food processing and storage, and medical refrigeration [7]. These systems consume large amount of energy, therefore, many studies have been appeared that examine the possibility of reducing power consumption in refrigeration system by improving COP of the system [9,3]. The COP can be improved either by decreasing compressor work or by increasing the refrigeration effect [9]. Compressor work can be decreased by using single stage compression instead of multistage compression. Increasing the refrigerating capacity is achieved by transit the refrigerants to subcooling after a condensation processes and superheating after an evaporation processes [11].

***The factors that improve the performance of VCRS are as follows:***

i. Thermodynamic characteristic of the refrigerant;
ii. The different ratios from a refrigerant mixture that are used into a refrigeration system;
iii. Suction pressure ;
iv. Discharge pressure;
v. The proportion between evaporator and condenser pressure pe / pc;
vi. Amount of the refrigerant that is filled into the system and ;
vii. Diameter of capillary tubes [1].

## 2. Literature review

In recent years several experiments and theoretical studies focused on the way to improve the performance of refrigeration systems by using mixtures of refrigerants or making improvements of the design of the compressor. Currently, nanotechnology has been employed to improve the heat transfer properties to ensure an increase in the efficiency of the system. Bolaji et al (2014) investigated theoretically replacing R134a with R152a and R600a in a VCRS. The investigation showed that the COP of R600a was the least one, whereas R152a was the highest one. The average COPs of R152a and R600a were 13.4% higher and 5.4% lower than that of R134a respectively, [12]. Tiwari et al (2014) used R125, R134a, R143a and R152a to replace R12 in a VCRS, and the experimental results showed that R152a was highest of COP among refrigerants. Also, R152a exhibited good environmental effects [13]. Matani et al (2013) studied a VCRS experimentally by using three types of refrigerant R134a, mixed from HC consists of (50 % R290 and 50% R600a), and R401a. Results showed that the most efficient one among three refrigerants was R134a, the COP of HC mixture (R290/R600a) is higher than other two refrigerants and COP of R401a is always lower than other two refrigerants [14]. Yennawar S, et al (2015) investigated VCRS using R134a and R600a.The investigation showed that the increasing of evaporator temperature causes the increasing of COP, while the increasing of condenser temperature causes decreasing of COP and COP of R600a was higher than of R134a [15]. Farayibi et al (2015) studied the effect of throttling variation on the COP of VCRS using R134a. The results showed that when the temperatures different of the evaporator increased from 8.66°C to 24.65°C, refrigeration effect increased from 141.2 kJ/kg to 144.6 kJ/kg whereas compressor work input decreased from 24.8 kJ/kg to 21.6 kJ/kg when the capillary lines increased from one to three. The COP of three capillary lines was the highest among others [10]. Shaik et al (2016) compared ten refrigerant mixtures by using propylene R1270 and propane R290 with R22 on a VCRS with different masses fractions start from M1 to M10. The results showed that M10 which consists of (85% R1270, 15% R290) was the highest refrigerating effect among ten mixtures while M9 which consists of (80% R1270, 20% R290) was the highest compressor work among ten mixtures compared with R22, the COP of M8 which consists of (75% R1270, 25% R290) was close to R22 [16]. Pilla et al (2017) used different masses fractions from two mixtures (R290 and R600a) on a VCRS. The results showed that the lowest and highest power consumption with the highest and the lowest COP were obtained for (60% R290, 40% R600a), (80% R290, 20% R600a), (60% R290, 40% R600a), (80% R290, 20% R600a) receptively [17]. ] Choudhari et al (2017) studied a VCRS by using R290 and R22. REFPROP 9.0 software was used to determine the properties of refrigerants. The results showed that R290 was lower discharge temperature; mass flow of R290 was 50% less than R22. However, COP of R290 is extremely close to R22. In addition, the R290 can be used as an alternative to R22 due to its excellent environmental, thermophysical properties and energy efficient performance [18]. Mishra (2018) made a simulation of VCRS by using (R134a, R404a, R407c and R290) for predicting the experimental behavior. The results investigated that the simulation predicts the experiment with deviation 5-10%, the COP of the VCRS by using R134a was better than R404a and 407c and the refrigeration effect of R404a was higher than the R407C [9]. Ikhar (2017) used the capillary tube as expansion valve with three different diameters 0.036 inch, 0.040 inch and 0.050 inch on VCRS which caused a variation of the performance of the system. This leads to obtain optimum capillary tube diameter for better performance [19]. Mishra et al. designed a model to compare experimental results of VCRS that included COP, second law efficiency and system exergy destruction ratio by using Engineering Equation Solver (EES) software. The results showed that the increase in the speed compressor causes reduction both of COP and the system exergy destruction ratio while improve of second law efficiency. Also, the results confirmed that the increasing of brine mass flow rate in the evaporator causes to improve both of COP and system exergy destruction ratio, while reducing second law efficiency. Finally increasing a water mass flow rate in the condenser causes to improve both of COP and system exergy destruction ratio, while reducing second law efficiency [20]. Al-Sayyab studied three different types of refrigerants, namely R134a, R290 and R600a with four different mixing ratio mix1consists of (70% R134a, 20% R290, 10% R600a), mix2 consists of (70% R134a, 10% R290, 20% R600a), mix3 consists of (50% R134a, 20% R290, 30% R600a), mix4 consists of (60% R134a,20% R290, 20% R600a), are used as alternatives to R134a. The results revealed that the obtained COP by the new mixtures are less than that of R134a, and the most suitable refrigerant that can be used instead of R134a was mix2. The COP of mix2 is 8 % less than that of R134a at 24 ℃ room temperature [21]. Gill et al. used a refrigerant mixture that consists of (28% R134a and LPG72% wt) to replace R134a in a VCRS. The results revealed that the COP of R134a and LPG was higher than R134a and lower compressor discharge temperature and the miscibility of R134a/LPG with mineral oil as a lubricant was good [22]. Devecioğlu and Oruç used R1234yf, R444A and R445A refrigerants on VCRS refrigeration system. The computations showed that R444A and R445A are having high cooling capacity; on the other hand, their values of performance coefficients were smaller compared to R1234yf, due to the increasing their electricity consumption. [23]. Investigated VCRS using different mixtures (40/60, 50/50, 60/40, 70/30 and 80/20 mass %) of R134a and R600a. The results showed that all the mixtures have a higher (COP) than R134a at evaporator temperatures varying between -30 °C to 12 °C. Also the results confirmed that the mixture of (50/50 R134a and R 600a) obtain 4.10 % increasing of COP of the system compared to the R134a and 3.73% deceasing in the power consumption [24]. Oruç and Devecioğlu compared experimentally R404A with R442A and R453A refrigerants, the results showed that R404A was the highest power consumption while R453A was the lowest one among three refrigerants. The cooling capacity of R442A and R453A increased from 1 to 8% compared with R404A. COP was better by 5 to 12% by using R442A [25]. Mishra investigated the performance of VCRS. The results showed that the COP of refrigeration system increases with increasing evaporator temperatures and decreases with increasing condenser temperatures and also the values of COP of R134a was slightly higher than R1234ze and R1234yf. In addition, the R1234az achieved an increase of COP of the system around 5 to 10 % compared to the R1234yf. Therefore, R1234ze can be replaced with R134a refrigerant in VCRS without system modification [26]

## 3. **Material and methods**

Setup of experiment: The welding process began to install the connections to connect them to the pressure and temperature meters. The welding process was done using carbon and oxygen cylinders and welding with silver wires as shown in the figure3.Four connections were welded for each compound outlet, for example at the exit of the compressor, after the condenser, at the exit from the capillary tube, and at the exit of the evaporator as shown in the figure .3

**Figure 3** Connection with hoses and silver wires.

Each hose connection was connected 4 times; two for the high pressure of the compressor outlet and the condenser outlet, its specifications are for four refrigerant fluids: R404a70, R22, R134a, and R407c. The maximum pressure reading is 38 bars, 550 psi. The temperature is in Celsius, and the minimum value is –45 degrees Celsius. The temperature is not 98 degrees Celsius for R134a refrigerant. There are two low pressure readings at the capillary tube and the evaporator outlet as shown in figure. 4

(a) (b)

**Figure 4** (a) low-pressure gauge b) high-pressure gauge.

, with the same specifications but different temperatures and pressures measure up to 18 bar, 260 psi, and from -45 to 64 degrees Celsius. The system was tested after the welding process and the system did not record satisfactory cooling capacity which means there is a leak in the system or problem in the welding joints. The system was then evacuated of gas and pressurized with air at a pressure 10 bars, it was noted by monitoring the pressure gauge that there was a decrease in pressure, which confirms the presence of a leak in the system. The detection process was carried out using a liquid, and through the liquid, bobbles were observed appearing after the filter, , which means that the welding process was not done properly, so leak site was welded and pressurized the system with air using a vacuum device to confirm whether there was another leak or not. After ensuring that the welding process was successful and that there were no leaks, the filter was also replaced with a new one and the capillary tube was cleaned of sediments and impurities, making the system ready for operation ,the system was evacuated the system of air using the same device and then recharged it with R134a refrigerant .The first charging process after the leakage problem was done through a dual gauge containing a high pressure gauge and a low pressure gauge and a 500g refrigerant cylinder and the empty cylinder weighed 150g which means that the first charge to the system was 350g, Then gradually charged it until reached 600 g the gas quantities was determined using an electronic balance and The two numbers are double, one for high pressure and the other for low pressure as shown below Figure .5

**Figure 5** Charging of R134a

Welding process is shown in Figure .6. In the laboratory of College of Mechanical Engineering Technology, the system was operated under normal conditions both pressure and temperature readings were taken at various points, including the compressor, condenser, and evaporator.

(a) (b)


(c) (d)

**Figure 6** (a-b) real demotic refrigerator (c) a new filter (d) Welding process to install the gages.

, refrigeration systems was operated by R134a as a refrigerant as a result of good properties such as compatible with all kinds of oxide, it works safely; it has no effect on the ozone layer, it has flammability, inexpensive, and most research depends on it in studying the refrigeration systems, the specifications of R134a as shown in table.1. Relying on a set of gages installed at entrance and exit of each component of the cycle, the change in pressure and temperature is monitored, the specifications of the system as shown in a table .2.The tank is made of iron in a cylindrical shape placed transversely. The diameter of the tank is 35 cm and its length is 47 cm. Then it was insulated with 4 cm thick Arm Flex foam insulation. DC charge line with a length of 75 cm and a diameter of 125.0 cm. The evaporator tubes were wrapped 16 turns around the tank, and the tube diameter is 0.95 cm, then the suction line extends from the end of the evaporator to the compressor with a length of 130 cm and a diameter of 0.95 cm. Insulated common materials include fiberglass, rubber foam, and polyethylene to prevent heat loss to the external medium as shown in figure .7 .The tank was filled with water by taking advantage of heat absorbed from the working fluid (R134a), the water is cooled directly inside the tank. A connected pipe was installed between the tank and two water taps to obtain cold water, the condenser is designed in the shape of a square, 27 cm long x 27 cm wide, 9 cm deep. The total length of the copper tubes in the condenser is 73 cm, and the total number of turns is 26 of which are vertical and 18 are horizontal, The filter is 10 cm long and 2 cm in diameter, and capillary tube with an outer diameter of 0.15 cm, 10 turns, and each circle has a diameter of 2 cm. .A half-horsepower compressor is designed with a frequency of 50 Hz and an electrical voltage of 220-240 volts.

(a) (b) (c)

**Figure 7** Arm Flex foam insulation of the evaporator tube inside the tank (b) the connected pipe(c) manufactured system.

**Table 1.** Specifications of R134a [27].

| SN | Specifications | | No | Specifications | |
|---|---|---|---|---|---|
| 1 | Name | 1,1,1,2 Tetrafluoroethane | 11 | $P_{sat,v}$ at 20°C | 774.3 kPa |
| 2 | Formula | $CF_3CFH_2$ | 12 | hg | 198.6 kJ/kg |
| 3 | $M_W$ | 102.03 g/mol | 13 | $\rho_{,L}$ | 1294.8 kg/m$^3$ |
| 4 | Chemical state | pure | 14 | $\rho_{,v}$ | 14.43 kg/m$^3$ |
| 5 | ASHRAE | A1 | 15 | $Cp_{,L}$ | 1.341 kJ/kg°C |
| 6 | ODP | zero | 16 | $Cp_{,v}$ | 0.90 kJ/kg°C |
| 7 | $GWP_{,100,year}$ | 1300 | 17 | $K_{,L}$ at 25°C | 0,0824 W/m K |
| 8 | $T_{,critical}$ | 101.1°C | 18 | $K_{,v}$ at 25°C | 0,0145 W/m K |
| 9 | P, critical | 4.06.3 MPa | 19 | μ ,L at 25°C | 0,202 mPa.s |
| 10 | NBP | -26.4 °C | 20 | μ ,V at 25°C | 0,012 mPa.s |

**Table 2**. Technical Detail of the Experimental System.

| SN | Component | Specifications |
|---|---|---|
| 1 | Tank | cylindrical shape |
| 2 | Compressor | Bitzer 1/2 HP |
| 3 | Condenser | Air cooled |
| 4 | Evaporator | Water cooled |
| 5 | cable tube | An outer diameter of 0.15 cm |
| 6 | Voltage | 220 -240 volts |
| 7 | Suction lines | 130 cm copper pipe |
| 8 | Discharge lines | 1/4-inch copper pipe |
| 9 | Frequency | 50 Hz |
| 10 | DC charge line | 75 cm and a diameter of 125.0 cm |
| 11 | Door type | Single closed door |

### 3.2 Experiment procedure

To calculate the volume of the tank is used this formula:

$$V = \pi r^2 h \qquad (1)$$

Where r is the radius of the circular base (half of the diameter), and h is the height (or length) of the cylinder, after substituting the data into the equation (1) is obtained volume equal to 45.2193 liters. The process starts from the compressor entering the first point at the first connection and taking the reading directly from the meter. The first point is located in the saturated steam region, meaning x=1, and the second point was taken via temperature and pressure and is located in the superheated steam region, and the third point via pressure x=0 in the saturated liquid region In the expansion valve process, the fourth point means h3=h4 and is located in the mixture region as shown in figure .8

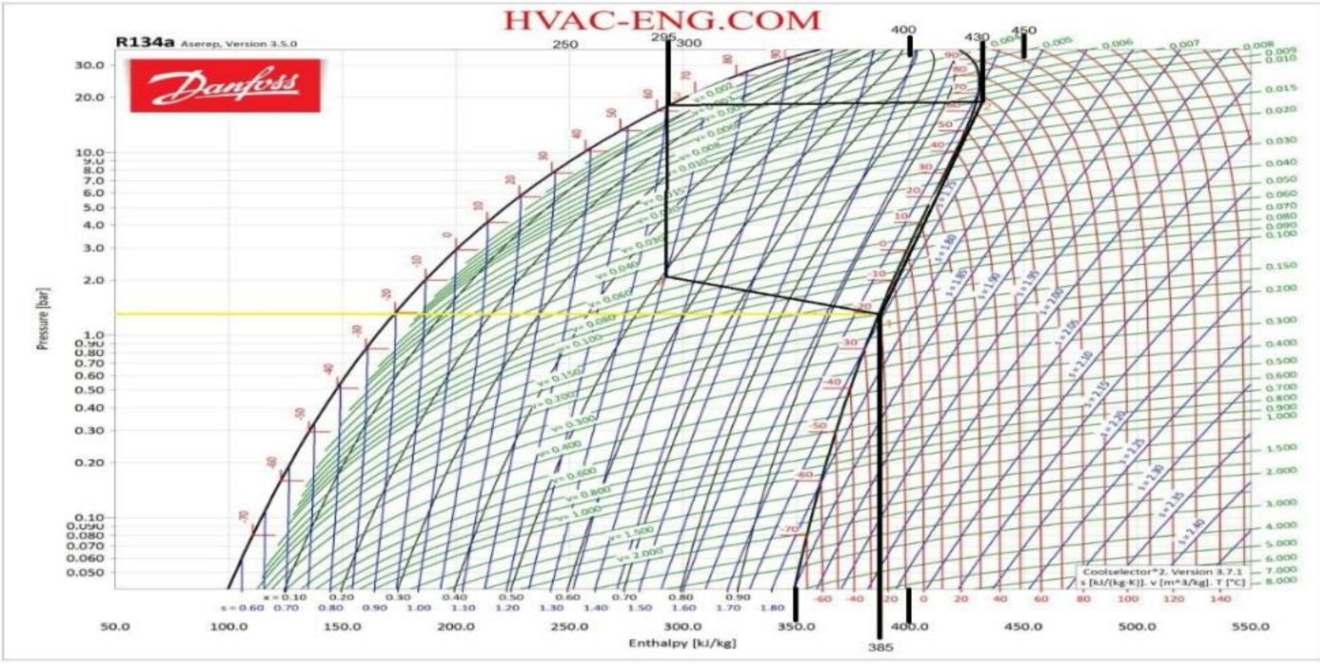



**Figure 8**. Phase change of R134a on the p-h diagram.

The following laws were used to determine work compressor, heat absorption and coefficient of performance of the refrigeration system [ 28]:

a) $W_{comp} = (h_2 - h_1)$ (2)

b) $Q_{evap} = (h_1 - h_4)$ (3)

c) $Q_{cond} = (h_3 - h_2)$ (4)

d) $COP = \frac{(h1 - h4)}{(h2 - h1)}$ (5)

A water cooler operating system that operates on 220V AC at 50Hz consists of several components that work in harmony to ensure proper operation. The circuit begins with the electrical source that powers the system, followed by the main switch, which allows current to flow when turned on, illuminating the green LED indicating the circuit is in operation. The current then flows to the thermostat; this switches the compressor on or off based on the water temperature. When the water reaches the desired temperature, the thermostat disconnects power to the compressor, and the red light illuminates, indicating that the cooling process has stopped. Meanwhile, the condensing unit fan motor cools the condenser to ensure the efficiency of the refrigeration cycle, the compressor motor relies on a rectifier to assist in starting, especially when high initial torque is required. Its terminals are indicated by the symbols R, S, and C (Run, Start, and Common). The circuit also contains a protective circuit breaker that automatically disconnects the power in the event of an overload or short circuit, providing protection for key components such as the motor and compressor and preventing electrical malfunctions or fires.

## 4. Results and discussion

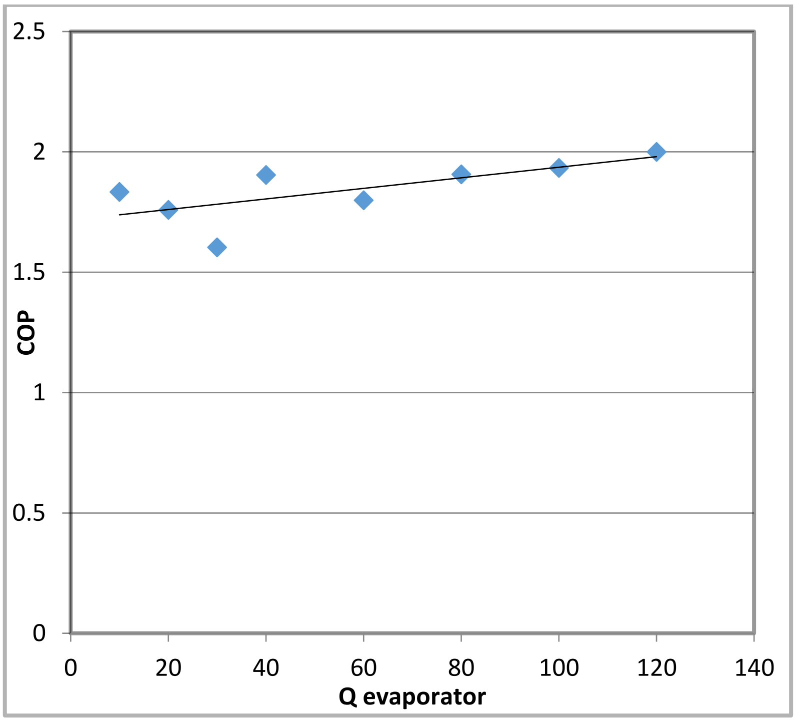
The process of calculating the results was done after solving the blockage problem by taking time in these calculations. These results were taken after operating the system 2 hours continuously under some assumptions, for example, unsteady state operation conditions, negligible change in the kinetic and potential energies, adiabatic system, no heat transfer from or into the system, negligible pressure drop and under normal conditions in the laboratory, as shown in tables 3 and 4

**Table 3.** The enthalpy of R134a at the inlet and exit of the compressor depends on the pressure and temperature.

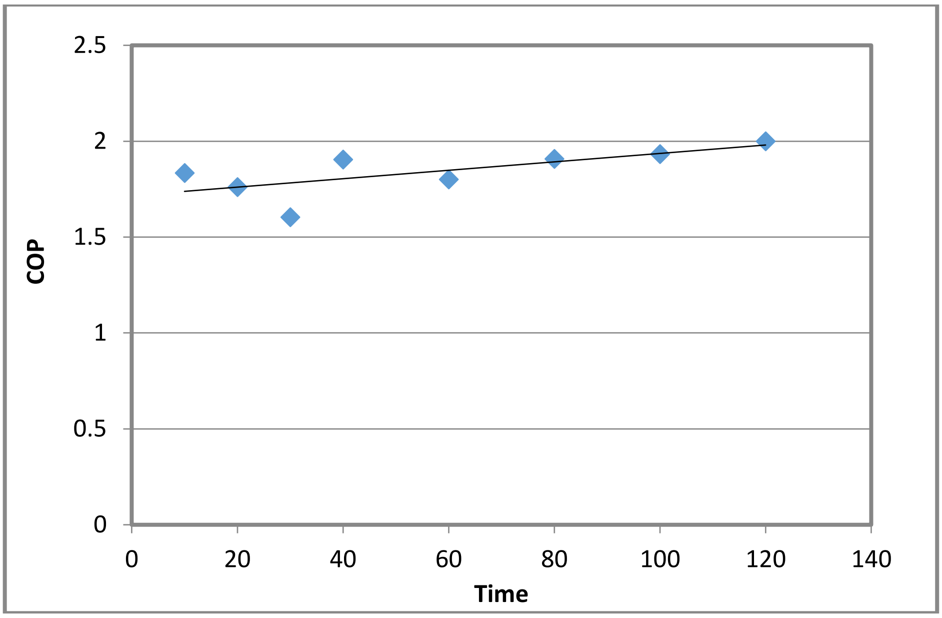
| Cases | Inlet of Compressor | | | Exit of Compressor | | |
|---|---|---|---|---|---|---|
| | $P_1$ (bar) | $T_1$ ($^0$C) | $H_1$ (kj/kg) | $P_2$(bar) | $T_2$($^0$C) | $H_2$ (kj/kg) |
| After 10 min | 1.1 | 23 | 385 | 19.8 | 67 | 433 |
| After 20 min | 0.9 | 30 | 380 | 18 | 62 | 430 |
| After 30 min | 1.3 | 20 | 387 | 22 | 73 | 435 |
| After 40 min | 1.1 | 23 | 385 | 18.9 | 67 | 427 |
| After 60 min | 1 | 25 | 385 | 17.5 | 62 | 435 |
| After 80 min | 1.3 | 20 | 387 | 21.5 | 71 | 430 |
| After 100 min | 1.3 | 20 | 387 | 20 | 68 | 432 |
| After 120 min | 1.3 | 20 | 385 | 19.5 | 66 | 430 |

**Table 4.** The enthalpy of R134a at the exit of the condenser and inlet of the evaporator depends on the pressure and temperature.

| Cases | Exit of condenser | | | Inlet of evaporator | | |
|---|---|---|---|---|---|---|
| | $P_3$ (bar) | $T_3$($^0$C) | $H_3$ (kj/kg) | $P_4$(bar) | $T_4$($^0$C) | $H_4$ (kj/kg) |
| After 10 min | 19.2 | 66 | 297 | 2.1 | 9 | 297 |
| After 20 min | 17.5 | 61 | 292 | 2 | 10 | 292 |
| After 30 min | 22.2 | 72 | 310 | 2.4 | 5 | 310 |
| After 40 min | 18.5 | 64 | 305 | 2 | 10 | 305 |
| After 60 min | 16 | 60 | 295 | 2 | 10 | 295 |
| After 80 min | 21.1 | 70 | 305 | 2.2 | -7 | 305 |
| After 100 min | 19.9 | 67 | 300 | 2.1 | -9 | 300 |
| After 120 min | 19 | 65 | 295 | 2.1 | -9 | 295 |




(a)




(b)

**Figure 9** (a) COP against cooling capacity (b) COP against time.

The Coefficient of Performance (COP) was calculated at various stages of the experiment. Initially, the COP was low, around 0.33, due to the blockage and poor gas flow. However, after the system was corrected, the COP improved significantly, reaching 1.5 after 120 minutes of operation. This improvement was a direct result of better gas flow and pressure-temperature stabilization. The system's performance showed gradual improvement as time progressed. For instance, at 70 minutes, the COP had increased to 1.93, reflecting better thermal efficiency and stabilization of system parameters. After 10 minutes, the values were initially unstable, with higher-than-expected pressures indicating an obstruction or poor flow of refrigerant. After 30 minutes, Pressure and temperature began to stabilize as the system adjusted to the operational parameters. After 1 hour: The system reached a semi-stable state, with pressure values nearing expected levels. The refrigerant flow was more efficient, and the cooling process improved after 90 and 120 minutes. The system's performance stabilized, with consistent pressure and temperature values. The COP reached its highest value at this point, indicating an optimal operating condition

## 5. Conclusion:

The experiment conducted on the simple refrigeration system revealed several critical factors affecting the system's performance and cooling capacity. The study focused on pressure, temperature, and enthalpy variations at different stages of the system. Throughout the experiment, multiple challenges were faced, including blockages, leakage, and system inefficiencies, all of which had a direct impact on the overall performance. Below is a detailed analysis of the experiment and its outcomes

- Blockages in the System: Initially, it was discovered that the temperature and pressure in the condenser were higher than the compressor gauge readings, indicating a blockage in the system, particularly within the filter and capillary tube. This caused a reduction in cooling efficiency.
- Welding and Connections: Some challenges arose during the welding and installation of connections between the components. Ensuring airtight seals and secure fittings was crucial to avoid leaks.
- Pressure and Temperature Management: Balancing pressure and temperature readings at various stages was a complex task. In the early stages, discrepancies in the pressure values suggested that further adjustments were necessary, but as the system ran for longer periods, it gradually achieved more stable operating conditions, so it is essential to monitor pressure and temperature readings consistently to ensure the system operates efficiently and avoids potential problems like overheating or undercooling.
- Proper Refrigerant Charge (R134A): The correct charge of refrigerant was essential to achieving optimal cooling. Overcharging or undercharging can negatively impact the cooling capacity and efficiency of the system. So with the right amount of refrigerant, the system was able to operate at its maximum potential.

- Pressure and Temperature Regulation: Precise regulation of pressure and temperature during the entire experiment was essential. It ensured that the system remained within the desired operating parameters, preventing overheating or underperformance.
- The cleaning of the filter and capillary tube was critical in restoring the system's cooling capacity. Removing the obstructions reduced the resistance to refrigerant flow and allowed for better performance.

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**Competing interests' statement**

The authors declare there are no competing interests

**Nomenclature**

| | |
|---|---|
| Hydrocarbons | HCs |
| Chloro fluoro-carbons | CFCs |
| Hydrochlorofluoro-carbons | HCFCs |
| Hydrofluorocarbons | HFCs |
| Ozone Depletion Potential | ODP |
| Global Warming Potential | GWP |
| Hydrofluoroolefin | HFOs |
| vapor compression refrigeration system | VCRS |
| Coefficient of performance | COP |

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