

## Influence of ZnO nano-refrigerant in R134a on performance compression systems of refrigeration

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### ABSTRACT

In the era of technological, advancements in various fields, refrigeration systems have a significant function in meeting human needs, and continuous research must be done by many researchers who are working to enhance the performance of these systems. Here, an attempt was made to enhance system performance. In the present work, the investigational investigations of ZnO nanoparticles at three amounts (0.2 %, 0.4 %, 0.6 %) are dispersed in polyalkylene glycol (PAG) oil with R134a refrigerant and it is test effect of three temps of water in the evaporator (40degree centigrade, 50-degree centigrade, 60-degree centigrade), it is observed that there is a decrease in the evaporator temp, an enhancement in the thermophysical characteristics of the nano-refrigerant, and maximum an enhancement in the performance coefficient is 24.92 percent at the temp of the water in evaporator 40-degree centigrade and 0.6 percent amount of nanoparticles, while, the power usage is reduced by 3 to 19 percent, and the temp is reduced by (40-degree centigrade – 17-degree centigrade). The investigational investigates show that the systems of refrigeration with nano-refrigerant works normally, just like any other system of refrigeration. Thus nano-particles can be applied to enhance the performance of hydrocarbon-based systems of refrigeration under test conditions.

**Keywords:** Refrigerant, Zinc oxide, nano-particle, polyalkylene glycol oil.

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### 1. Introduction

Thermo-physical characteristics of matter are very important in cooling and heating applications. It has been discovered that the efficiency of any device is primarily determined by its architecture, depending on the ability to conduction thermal, viscosity, and other factors the basic heat and mass of gases and liquids are integrated into the system [1-4]. Conventional fluids have a low ability to conduction thermal, and poor heat transfer, capability, limiting their efficiency. As result, there is an ongoing need to produce reliable and fluids capable of dealing with high heat transfer rates. Minor strong additives, usually in the micrometer range, are an excellent option, it has been utilized to enhance the thermal characteristics of fluids [5-7]. M.E. Haque, et al. [8] Investigationally, the addition of various sizes of (AL<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub>) of nano-particles to a lubricant (POE) with two various amounts (0.05 – 0.1 v percent ) was studied. Then tests of freezing capacity and energy usage of your refrigerator was a performance. The results demonstrated an increase in the performance factor of the refrigerator 19 percent and 22 percent at mentioned amounts, as well as the energy usage at (0.1 percent) amount of AL<sub>2</sub>O<sub>3</sub> and TiO<sub>2</sub> (27.73 percent - 14.19 percent) less than pure oil. From the results of the experiment, we conclude that the performance of the refrigerator is better with nano- lubrication oil compared to pure oil. R.S. Mishra, et al. [9] Studied the investigation of the added various nano-particles of (AL<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, CuO) in various refrigerants (R407c, R134a, R404A) and study the Thermophysical characteristics of nano refrigerant and the performance's coefficient of the system. the result demonstrates the thermal characteristics of the system increases by 15 percent to 94 percent, 20 percent, and 12 to 34 percent respectively and the specific heat is lower

in nano-refrigerants compared to the pure refrigerant, the R134a- AL<sub>2</sub>O<sub>3</sub> is highest 34 percent and with utilized various nano-particle and (R404A, R407) refrigerant the resulting enhancement in cop from 3-14 percent and 2 to 12 percent respectively. My work consists of an investigational design model a domestic refrigerator model of vapor compression. Our work focuses on comparing the performance's coefficient, compressor work, and cooling effect by replacing the traditional R134a refrigerant with nano-fluids (PAG + various TiO<sub>2</sub> nano-particle mass fractions) with R134a as a refrigerant. Omer A. Alawi et al. [10] explored the thermal characteristics of nano-particles suspended in refrigerant and lubricating oils. Study the effect of nano-lubricants on phenomena of two phases and boiling. The results demonstrated that nano-refrigerant with TiO<sub>2</sub> refrigerators work safely and normally and increase in heat transfer because the nano-particles have a much higher and strengthen the ability to conduction thermal compared with pure refrigerants. In Malaysia, Javari and Saidur [11] looked at the usage of nano-refrigerant in household freezers to decrease Emissions of CO<sub>2</sub> and electricity usage. They investigated the impacts of introducing two nanoparticles (AL<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>) to the mineral of oil R134a refrigerant with three mass fractions of (0.06 percent, 0.1 percent). Their findings indicate the highest savings for energy of 25 percent once 0.1 percent TiO<sub>2</sub> nanoparticles are applied onto mineral oil R134a, as well as a decrease of almost seven million tons of Carbon dioxide by 2030. The theoretical and practical effects of adding AL<sub>2</sub>O<sub>3</sub>-particles with nano-size to the refrigerant were investigated by Soliman et al. [12]. The investigational findings show a 9.11 percent rise in theoretical police and a 10.53 percent increase in real cops. Once nano-particles were utilized as a cooling load, the evaporator heating transfer coefficient expanded by 50 percent, and power losses has been decreased by 28 percent. The water heating transfer coefficient increased by 70.83 percent, and energy usage has been decreased by 13.30 percent, according to the theoretical results obtained. The performance pool AL<sub>2</sub>O<sub>3</sub>-particles that have a nano size with R134a/polyester was studied by Kedzierski [13]. Three various volume percentages of the mixed lubricant were employed, and R134a has been added to the mixture in a varied mass fraction. Since agglomeration of nano-particles exhibited heat transfer deterioration of about 14 percent, amounts increased by roughly 13 percent, 10 percent, and 9 percent for various combinations. Kuljeett Singh and colleagues [14]. A study of the performance of nano refrigerant (AL<sub>2</sub>O<sub>3</sub>+R134a) systems of refrigeration was conducted. With 0.5 percent AL<sub>2</sub>O<sub>3</sub>, the performance's coefficient has been shown to increase the most (7.2 to 8.5 percent). Once the mass fraction of nanoparticles in the refrigerant cop has been raised to 1 percent, it is lower than pure R134a.

## 2. The objective of the paper

The goal of this research is to test the performance of a vapor compression system using nano-particles ZnO and R134a as the refrigerant. Depending on the specifications of this research paper, a new vapor compression refrigeration test system was constructed. Three amounts (0.2 %, 0.4 %, and 0.6 %) of ZnO nanoparticles with a size of 50 nm were blended with PAG oil as lubricant and R134a as a refrigerant. The goal of the investigation is to demonstrate how nanoparticles blended with PAG oil can reduce compressor power usage and enhance heat transferability in the system. Once comparing the performance of a system with nanoparticles to the performance of a system with pure refrigerant, the performance coefficient of the system with particles that have nano-size comes out on top.

## 3. Experiment setup

Design the refrigeration test rig for compression. The test rig is made up of the compressor, a condenser, a capillary tube, and the evaporator. The reciprocating compressor is hermetically sealed, the evaporator is a cylindrical one in the form of a spiral coil and is fully immersed in water and made of copper. A condenser is a finned coil in a heat exchanger that is also made of copper. A sensor was utilized to measure temps at the inlet and outlet of the main parts. A temp scanner was utilized. An energy meter was utilized at the compressor to find out the amount of energy expended in it. Before charging the device with gas and nano-materials, the system was thoroughly checked for leaks. After the leak test, with the help of a vacuum pump, the device was evacuated of moisture to be charged with the nano-fluid and refrigerant. In this case, use R134a refrigerant. Due to its low ozone layer depletion potential and close thermodynamic characteristics [15, 16].

### 3.1. Nano-lubricants preparation:

The nanofluid was prepared by adding a nanoparticle (ZnO) to the base liquid is PAG oil. The weight of the nanoparticles for each amount was calculated from Equation 1, and the required weight was estimated using a sensitive balance and the nanoparticle amount was mentioned in Table 1 and the nanoparticle lubricant was

prepared in a two-step manner, by adding a nanoparticle size mass (0.2 percent, 0.4 percent, 0.6 percent) to the PAG oil and placing the mixture on a magnetic stirrer for 1 hour, transferring the mixture to an ultrasonic cleaner. For three hours, the steps can be seen in figure1 After the nano-lubricant has been prepared, it is injected into the compressor through the injection device, and then the compressor is charged with refrigerant, and the process of taking readings begins.

$$\varphi \text{ percent} = \frac{(m_p \backslash \rho_p)}{(m_p \backslash \rho_p) + (m_{bf} \backslash \rho_{bf})} \tag{1}$$

Table1. The volume fraction of nano-particles

The amount of nanoparticles	Mass of ZnO nanoparticles
0.2 percent	2.25g
0.4 percent	4.5g
0.6 percent	6.8g

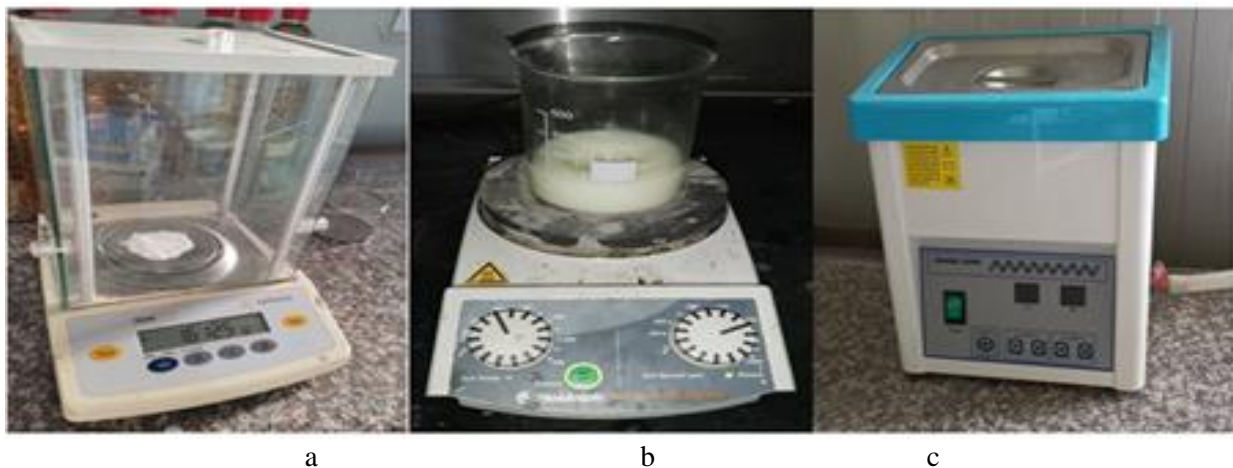


Figure 1. The equipment, utilized in the investigational rig (a) the electronic balance (b) stirring hotplate (c)ultrasonic cleaning

### 3.2. Charging of set up

To avoid the negative impacts of moisture, it must empty the gadget before charging it. The charging of the system is then finished. The nano-fluid is initially applied to the compressor, where it is injected via the service port into the compressor and made to stable for 15-20 min before being charged with R134a. Once the pressure gauge demonstrates, the charging phase must be terminated.

### 3.3. Work of an investigational test rig

Vapor pressure relies on a flowing liquid refrigerant to absorb and remove heat, reject the cooled area, and then reject heat from elsewhere. Figure 2 depicts a conventional single-stage vapor pressure system. An evaporator, a capillary, a condenser, and a compressor all seem to be components of these systems. The temp increases as a consequence. Its heated vapor has been sent to the condenser, where it is cooled into a liquid by passing thru a coil or tube with cold air. Condensed Refrigerant is a kind of refrigerant that is compressed into. In thermodynamics, a saturated fluid is directed thru a capillary tube in which there is a sudden pressure drop, which decreases pressure in the evaporation of a statical flash of the refrigerant element if the cold blend is then directed through the coil from the evaporator in which it absorbs heat from the environment. The coolant evaporated and returns to the compressors to be cooled, and the cycle is repeated[17].

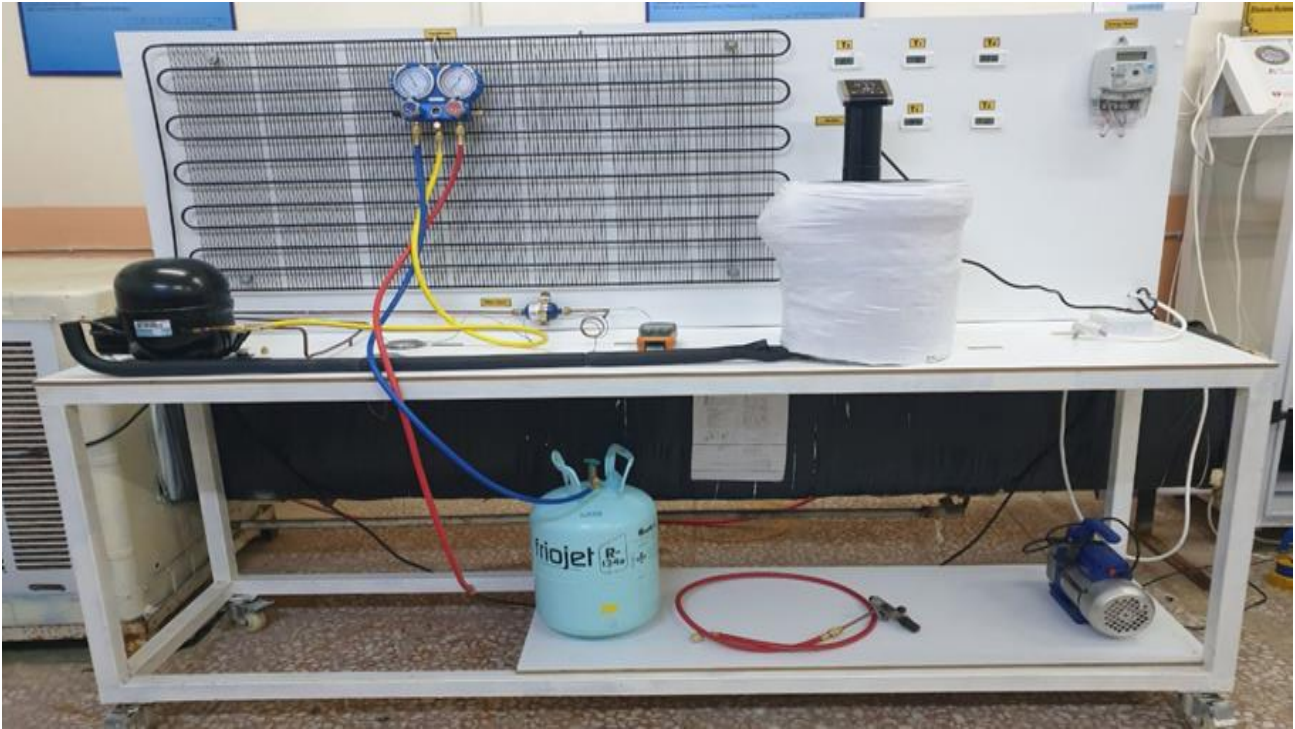


Figure 2. Experiment test rig

#### 4. Theoretical analysis

Nano-refrigerant thermo-physical characteristics are computed in two stages. Firstly is calculated the thermophysical characteristics of the nano-particles oil mixture, and this information is utilized to compute the characteristics of nano-refrigerant, and the equations are utilized to calculate the performance of the system

##### 4.1. Calculation of nano-lubricant thermo-physical characteristics

The following correlation is utilized to calculate the thermophysical characteristics of nano-lubricant.

Density of nano-lubricant

$$\rho_{n,o} = (1 - \psi_n) \rho_o + \psi_n \rho_n \quad (2)$$

Specific heat of nano-lubricant (pak and cho)

$$c_{p,n,o} = (1 - \psi_n) c_{p,o} + \psi_n c_{p,n} \quad (3)$$

The ability to conduction thermal of nano-lubricant(Hamilton and Crosser)

$$K_{n,o} = K_o \left( \frac{K_n + 2K_o - 2\psi_n(K_o - K_n)}{K_n + 2K_o + \psi_n(K_o - K_n)} \right) \quad (4)$$

##### 4.2. Calculation of thermo-physical characteristics of nano-refrigerant

Density of nano-refrigerant

$$\rho_{n,r,o} = [(X_{n,o}/\rho_{n,o}) + ((1-X_{n,o})/\rho_r)]^{-1} \quad (5)$$

Specific heat of nano-lubricant

$$c_{p,r,n,o} = (1 - X_{n,o}) c_{p,r,o} + X_{n,o} c_{p,n,o} \quad (6)$$

The ability to conduction thermal of nano-refrigerants (Baustian et)

$$K_{n,r,o} = K_r (1 - X_{n,o}) + k_{n,o} X_{n,o} - (0.72 X_{n,o} (1 - X_{n,o}) (K_{n,o} - K_r)) \quad (7)$$

##### 4.3. Calculation performance's Coefficient:

a. tank's Volume

$$V = \pi/4 D^2 h \quad (8)$$

b. Water's Mass

$$m = \rho \cdot v \quad (9)$$

c. Power input to compressor

$$P = ( E_o - E_i ). 3600 \tag{10}$$

d. Refrigeration impact

$$RE = M_w cp_w dT \tag{11}$$

e. Performance's Coefficient

$$COP = \frac{M_w cp_w dT}{( E_o - E_i ). 3600} \tag{12}$$

**5. The results and discussion**

During the investigational investigation, four cases were considered. Initially, R134a and PAG oil were utilized in the test, and then three amounts of ZnO (0.2 %, 0.4 %, and 0.6 %) nanoparticles were tested with PAG oil and R134a refrigerant. Experimentation was conducted with a vapor compression systems of refrigeration to enhance the performance. The results of the investigational investigates are described below.

**5.1. Refrigeration effect**

Figure 3 demonstrates the differences in refrigeration effect for pure refrigerant and with nano-refrigerant. At evaporator water temp 40 degrees centigrade, the cooling effect increases by approximately 2.2503 percent, 5.7896 percent, and 7.256 percent for amounts of 0.2 %, 0.4 %, and 0.6 %. At the same amounts, the rise is 4.999 percent, 7.522 percent, and 10.684 percent at 50 degrees Celsius. Eventually, once the water in the evaporator is heated to 60 degrees Celsius, the amount increases by 7.851 percent, 10.799 percent, and 15.385 percent. Once comparing all of the findings to pure refrigerated air.

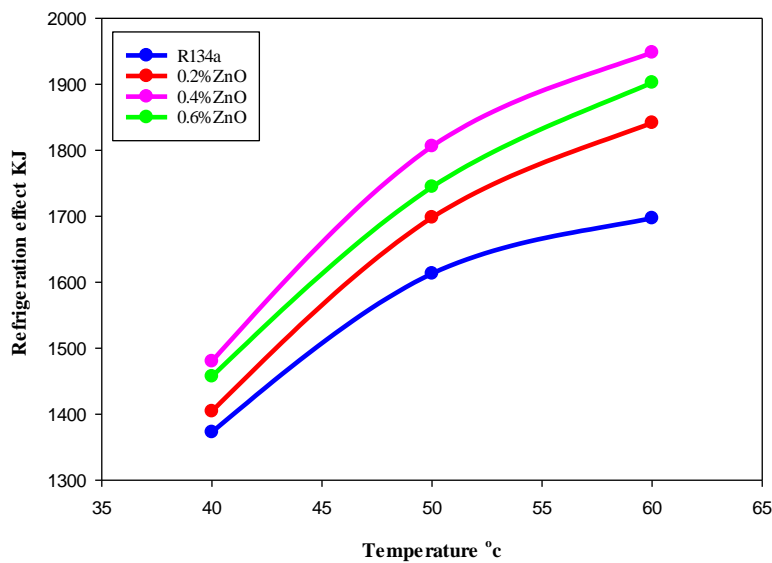


Figure 3. Relation between Refrigerating effect and temps of the evaporator

**5.2. Power usage**

**5.2.1. The differences between the compressor's power usage and various amounts of nanoparticles ZnO at temp 40 degrees centigrade**

Figure 4 demonstrates the difference between the power usage of the compressor and various amounts of nano-particles ZnO at temp 40 degrees centigrade. The power usage once compressor running with nano-lubricant containing (0.2 %, 0.4 %, 0.6 %) ZnO nano-particles are reduced about 11.023 percent,



14.286 percent and 19.048 percent. It is observed once compared results with pure refrigerant the power usage is decreased at an amount of ZnO increases.

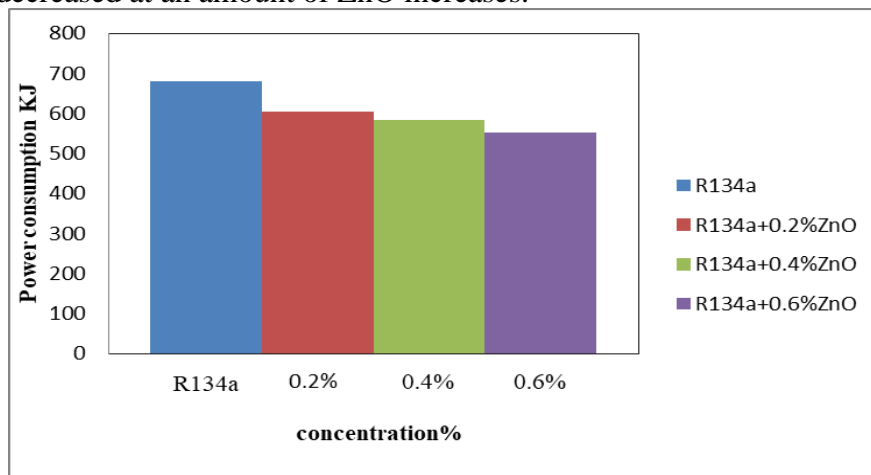


Figure 4. The different power usage at various amounts of nano-particles

### 5.2.2. A Difference between the compressor's power usage and various amounts of nanoparticles ZnO at temp 50 degrees centigrade

The difference between the power usage of the compressor and various amounts of nanoparticles ZnO at temp 50 degree centigrade demonstrated in figure 5. The power usage once compressor running with nano-lubricant containing (0.2 %, 0.4 %, 0.6 %) ZnO nano-particles are reduced about 9.633 percent, 11.009 percent, and 13.2467 percent. it is found once compared results with pure refrigerant the power usage is decreased at an amount of ZnO increases.

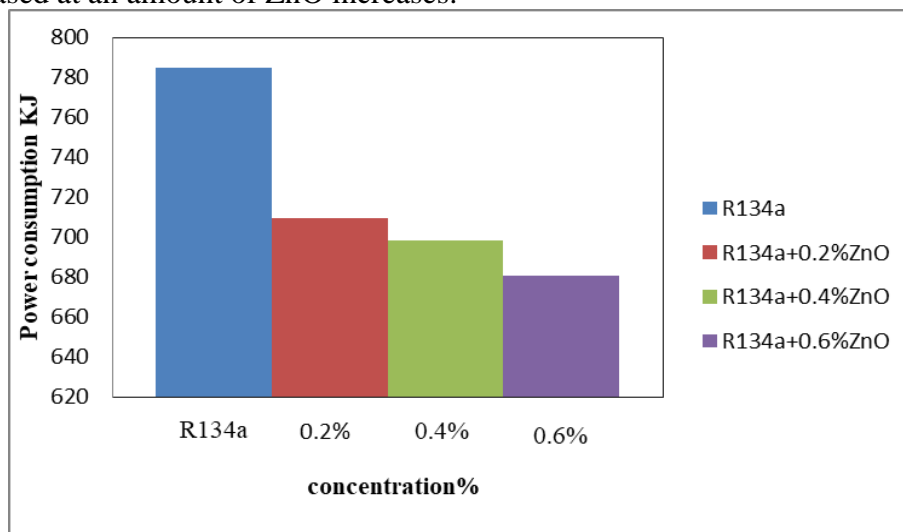


Figure 5. Difference between power usage and various amounts of ZnO

### 5.2.3. The difference between the power usage of the compressor and various amounts of nanoparticles ZnO at temp 60 degrees centigrade:

Figure 6 demonstrates the difference between the power usage of the compressor and various amounts of nano-particles ZnO at temp 60 degrees centigrade. The power usage once compressor running with nano-lubricant containing (0.2 %, 0.4 %, 0.6 %) ZnO nano-particles are reduced about 3.0434 percent, 10 percent, and 12.609 percent, once compared with pure refrigerant. it is found once compared results with pure refrigerant the power usage is decreased at an amount of ZnO increases.

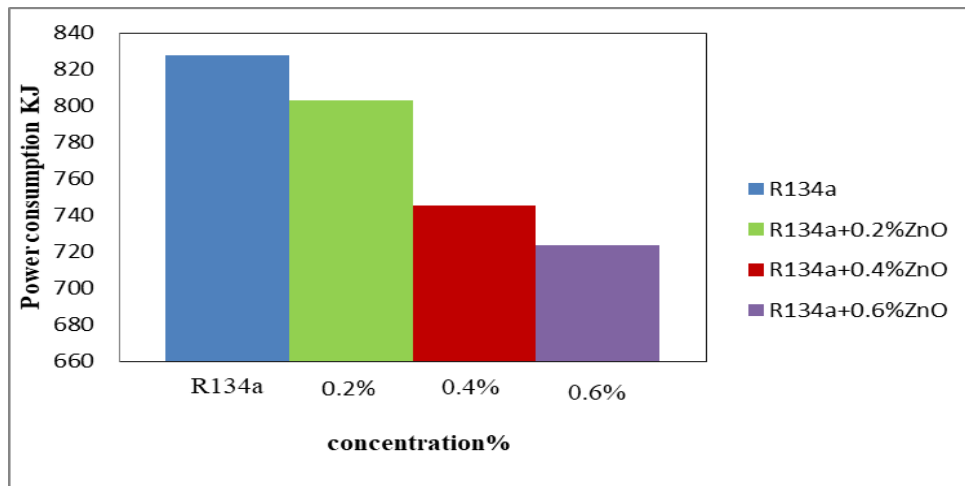


Figure 6. Difference between power usage and various amounts of ZnO

### 5.3. Performance's coefficient (COP)

#### 5.3.1. Difference between the performance's coefficient for pure refrigerant R134a with various amounts of nano-particles(ZnO) at temp 40 degrees centigrade

Figure 7 demonstrates the difference between the performance's coefficients of various amounts of nano-particles at a temp 40 degree centigrade with pure refrigerant, the COP of pure refrigerants is found 2.01757, and COP in amount 0.2 percent of ZnO is 2.3198, and the COP in amount 0.4 percent is found 2.4984 and COP in an amount 0.6 percent of ZnO is 2.68723. The enhancement of COP is 13.028 percent at amount 0.2 percent, and at amount, 0.4 percent is 19.246 percent, and the enhancement at 0.6 percent amount is 24.92 percent. That COP of vapor compression systems of refrigeration is enhanced. All these results in above compared with pure refrigerant.

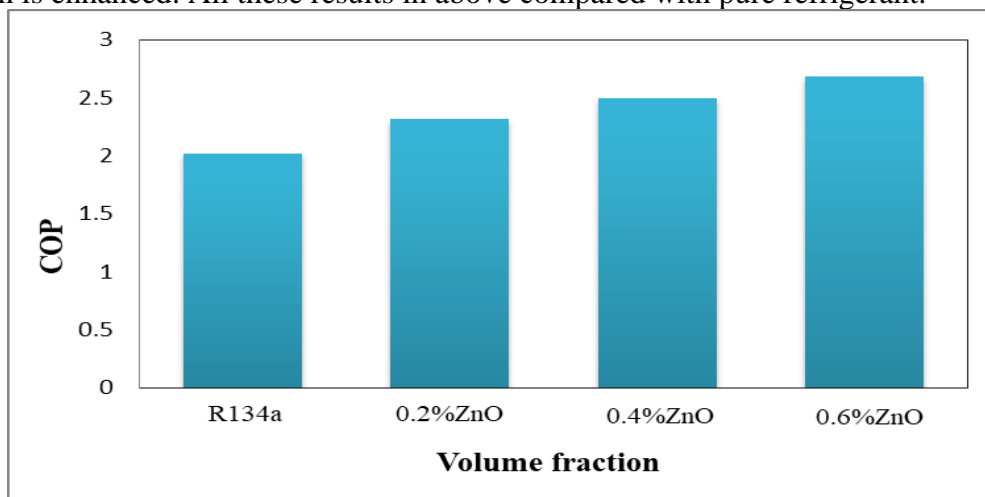


Figure 7. Difference cop for pure R134a with varying amounts of ZnO

#### 5.4.5. Difference between the performance's coefficient for pure refrigerant R134a with various amounts of nano-particles (ZnO) at temp 50 degrees centigrade.

Figure 8 demonstrates the difference between the performance's coefficients of various amounts of nano-particles at a heater temp 50 degrees centigrade with pure refrigerant, the COP of pure refrigerant is found 2.05579, and COP in an amount 0.2 percent is demonstrated 2.3946, and COP in amount 0.4 percent is found 2.498023 and COP in amount 0.6 percent ZnO is 2.6532. The enhancement in performance's coefficient is 14.149 percent at an amount of 0.2 percent, and the amount of 0.4 percent is 17.703, and at amount, 0.6 percent enhancement is 22.514 percent. All these results in above compared with pure refrigerant.

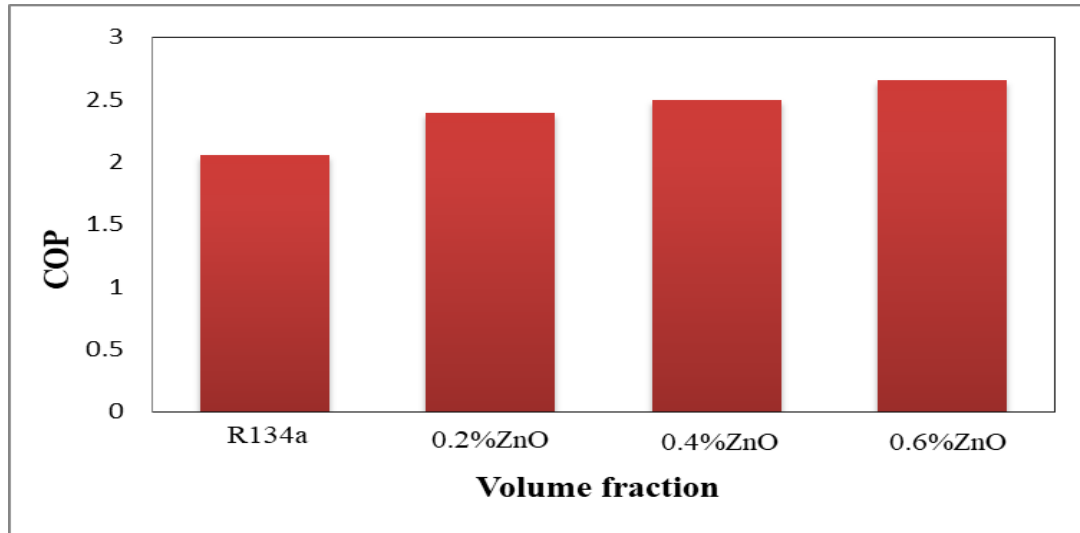


Figure 8. Difference cop for pure R134a with varying amounts of ZnO

#### 5.4.6. Difference between the performance's coefficient for pure refrigerant R134a with various amounts of nanoparticles (ZnO) at temp 60 degrees centigrade.

Figure 9 demonstrates the difference between the performance's coefficients of various amounts of nanoparticles at temp 60 degrees centigrade with pure refrigerant, the COP of pure refrigerants is found 2.04967, and the COP in amount 0.2 percent is demonstrated 2.2941, and at amount, 0.4 percent is found 2.5531 and COP in an amount 0.6 percent is found 2.692. The enhancement of COP is 10.655 percent at amount 0.2 percent, and at 0.4 percent amount enhancement is 19.719 percent, and in an amount, 0.6 percent is 23.861 percent, all these results in above compared with pure refrigerant.

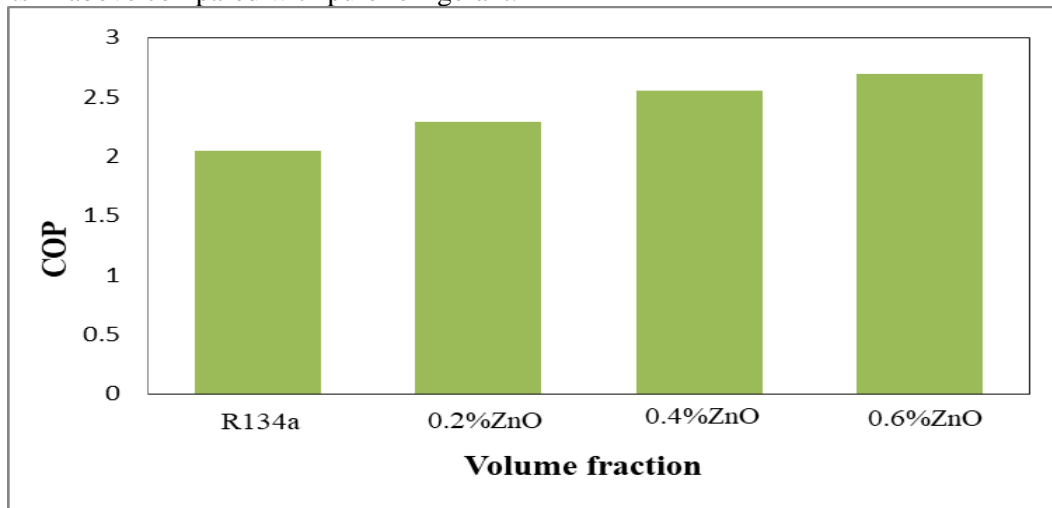


Figure 9. Difference for pure R134a with various amounts of ZnO

### 5.4. Thermo-physical characteristics of nano-refrigerant

#### 5.4.1. The ability to conduction thermal

Figure 10 demonstrates the difference between the ability to conduction thermal of pure refrigerant and nano-refrigerant. It is found the enhancement of the ability to conduction thermal at amounts (0.2 %, 0.4 %, 0.6 %) nano-particles are (4.108 percent, 11.76 percent, 23.16 percent), from results it is found the ability to conduction thermal of nano-refrigerant increased with increase nano-particle amounts once compared with the ability to conduction thermal of pure refrigerant R134a.



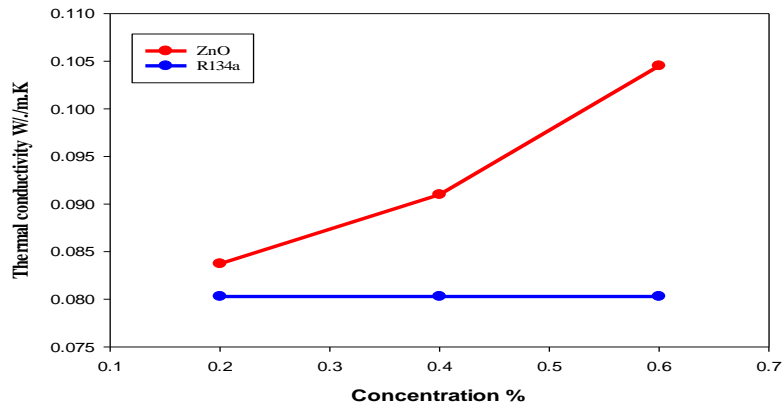


Figure 10. The ability to conduction thermal and various amounts of nano-particles

#### 5.4.2. The density of nano-refrigerant

Figure 11 demonstrates the difference between the density of pure refrigerant with various amounts of nano-particles. It is observed the enhancement of density at amounts (0.2 %, 0.4 %, 0.6 %) of nano-particles are (2.726 percent, 5.96 percent, 8.96 percent), from results show increased nano-particle amounts that increase the density of nano-refrigerant once compared with pure refrigerant R134a.

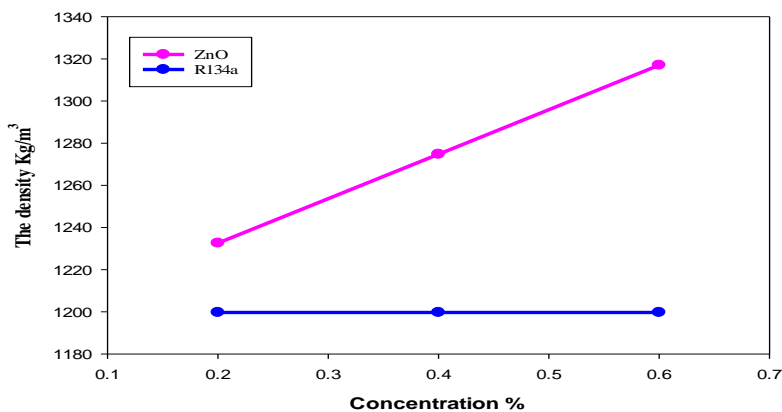


Figure 11. The density and amounts

## 6. Conclusion

In this study, an investigational investigation of a Vapour Compression System of refrigeration with ZnO nano-particles in PAG oil and R134a refrigerant is carried out. The size of the nanoparticles (ZnO) was 50 nm, and three amounts were utilized (0.2 percent, 0.4 percent, 0.6 percent). In this study, three water temps (40, 50, and 60 degrees centigrade) were utilized in the evaporator. The enhancement in the performance's coefficient is the greatest rise of the system, at 24.92 percent, according to the findings. and a max enhancement of 15.385 percent in refrigeration impact. The compressor consumes 19.048 percent of the total energy utilized. It's accessible at a 0.6 percent nanoparticle amount. Once pure refrigerant R134a is compared to the aforementioned findings, the performance's coefficient and thermophysical characteristics increase.

### Nomenclature

D: Diameter of the tank water

H: Water tank's Height

$\rho$ : Pure water Density

E: Readings of the energy meter

M : Mass in the tank

cp: Specific heat

dT: Various temp

$\rho$ : Density

K: The ability to conduction thermal

$\psi$ : Volume fraction

$\phi$ : Mass fraction

X: Amount

### Subsripts

O: PAG oil

n: TiO<sub>2</sub> nanoparticles

r: R134a Refrigerant

w: water

n,o: nano-lubricant

n,r,o: nano-refrigerants

### Abbreviations

COP: Performance's coefficient

TiO<sub>2</sub>: Titanium oxide

HFC: hydro- fluorocarbons

PAG: polyalkylne Glycol

VCR: Vapour compression systems of refrigeration

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