Experimental Investigation of Vapour Compression Refrigeration System by comparing the results procured after using pure refrigerant R134a with and without Titanium Oxide Nanoparticle

Dissertaion-II

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

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IN

MECHANICAL ENGINEERING

By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled **"Experimental Investigation of Vapour Compression Refrigeration System by comparing the results procured after using pure refrigerant R134a with and without Titanium Oxide Nanoparticle"** in partial fulfillment of the requirement for the award of 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 (Satnam Singh, Assistant Professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other Univesity 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

DECLARATION

It is here by declared that the work presented in Dissertation 1 entitled **"Experimental Investigation of Vapour Compression Refrigeration System by comparing the results procured after using pure refrigerant R134a with and without Titanium Oxide Nanoparticle."** as partial fulfilment of the requirements for the award of degree of M.Tech. (Thermal) in Mechanical Engineering, Department of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab, has been carried out by me. Further, it has not been submitted in part or whole to any institution or university for the award of degree or diploma. If any material found copied, legal action may be taken against me.

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I express my sincere gratitude to my guide, Mr. SATNAM SINGH, Assistant Professor, Mechanical Engineering Department, Lovely Professional University, Phagwara for kindly providing me an opportunity to work under his supervision and guidance. I would also like to acknowledge the technical assistance provided from the side of my technician without whom I think the construction of my experimental setup wouldn't have possible.

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ABSTRACT

Vapour Compression Refrigeration system basically is the device which absorbs heat from a lower body temperature and rejects it to the body or environment at higher temperature at the expense of some external work done on it. It is widely used everywhere ranging from commercial use in homes and shops to large scale and heavy cooling loads in industries. They vary in size and capacity as per their cooling requirements. In order to achieve high cooling loads with lesser energy or power consumption by the compressor and work with high performance It has always been the area of interest for plethora of researchers working in thermal engineering field.

With the advent of nano technology in every science and technology field, the field of Refrigeration is also now not left untouched of it. Its been seen that some of the metals and its compounds have high heat dissipation capacity, this formed the basis of its use in refrigeration. Many of the nano size metal compounds have been tested with many of the refrigerants and optimum concentrations have been found to ensure the enhanced Coefficient of performance of the VCRS.

In this work also a unique combination is taken and study is to be performed on VCRS. Here the mixing of nanoparticles of metal TiO2 of size 30-50 nm is done with refrigerant R134a and the attempt of finding the optimum concentrations is to be done.

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ABBREVATIONS

SiO_2	Silicon di Oxide
TiO_2	Titanium di Oxide
CuO	Copper Oxide
Al_2O_3	Aluminium Oxide
MNRO	Mineral Based Nanorefrigerant Oil
HFC	Hydro Flouro Carbon
CNT	Carbon Nano Tube
HVAC	Heating Ventilation and Air Conditioning
VCRS	Vapour Compression Refrigeration System
COP	Coefficient of Performance
Gm	gram
Kwh	Kilowatt Hour
Psi	pounds per square inch
Min	Minute
°C	Degree Celsius
T_1	Compressor outlet or Condenser inlet
T_2	Condenser outlet or Expansion Valve inlet
T_3	Expansion Valve outlet
T_4	Evaporator Section Temperature
T_5	Atmospheric Temperature
P_1	Compressor Outlet
P_2	Compressor Inlet
COP I	COP when R134a (100 gm) inserted
COP II	COP when R134a (100 gm) + 0.2 gm TiO2 inserted

COP III	COP when R134a (100 gm) + 0.4 gm TiO_2 inserted
COP IV	COP when R134a (100 gm) + 0.6 gm TiO_2 inserted
PAG Oil	Poly alkylene glycol
R134a	Tetra Flouro Ethane
R404a	blend of HFC 125, 143a, 134a
R507a	blend of R125 and R143a
R125	Pentaflouro ethane CH_3CHF_2
R290	Propane
R600a	Isobutane
R410a	blend of R32 (CH_2F_2), R125 (CH_3CHF_2)
R407c	blend of di, penta and tetra flouro ethane
R152a	di flouro ethane ($C_2H_4F_2$)
R718	water

CHAPTER 1: INTRODUCTION

1.1 INRODUCTION

With advent of nanotechnology, the scope in various areas of research has been proliferated tremendously. In Refrigeration and air conditioning field also this effect has been felt. Researchers are continuously finding out the ways to use this technology for enhancement of this area. A lot of work is also been done on this and a new class of refrigerant has already been introduced popularly known as nanorefrigerant. Various combinations have been introduced on these kinds using various basic refrigerants with metals or metal oxides. The metal oxides commonly used are TiO_2, CuO, Al_2O_3 etc. Figure 1 provides the better understanding of the size of nanoparticles.

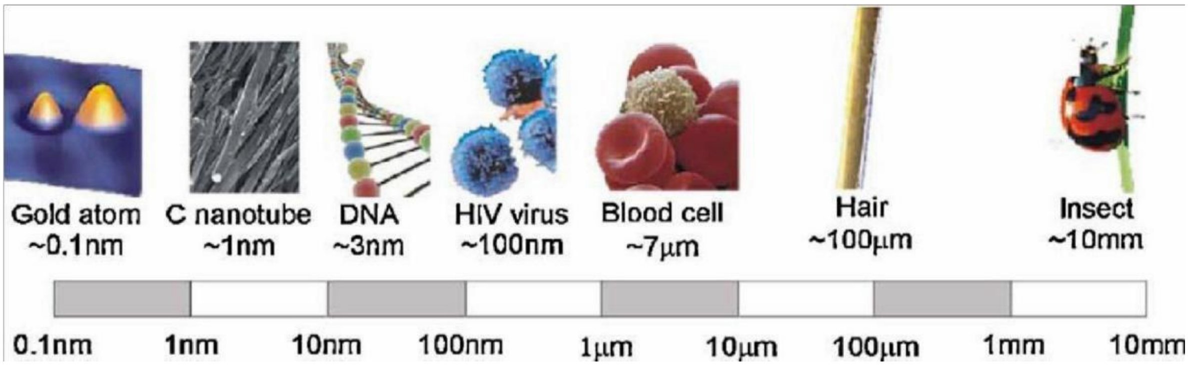


Figure 1

Length Scale of Nanofluid

Source: Serrano E (2009)

Nanorefrigerants are defined as the suspension of nanoparticles in base refrigerant. Some of the typical and popular nanorefrigerants are R600 based CuO nanorefrigerant, R134a based Al2O3 nanorefrigerant etc. At the starting age of this new research field, the nanofluids were basically used with the aim to proliferate the heat transfer rate since it was known that metals have higher thermal conductivity and therefore it can be used in the refrigeration systems to increase the heat dissipation rate and thereby can increase the overall COP of the system. Researchers are finding out the optimum concentration of nanoparticles that can be mixed in the refrigerant gas so as to have maximum heat dissipation from the refrigeration system. We here will also try to use the TiO_2 nanoparticles in three different mass concentration decided as 0.2, 0.4, 0.6 gram with around 100 gram of R134a refrigerant gas. Once only R134a gas would be inserted into the system and evaporator section would be maintained at three different temperatures we opted for 20, 25, 30 degree Celsius.

Compared to conventional solid–liquid suspensions for heat transfer intensifications, nanofluids possess the following advantages:

- High specific surface area and therefore more heat transfer surface between particles and fluids.
- High dispersion stability with predominant Brownian motion of particles.
- Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
- Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
- Adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations to suit different applications.

More the thermal conductivity of fluid more will be its heat transfer coefficients as compared to the one with lower thermal conductivity.

Therefore a lot of researches is going on to increase the thermal conductivity of the nanorefrigerants. The same has been presented here also.

1.2 APPLICATIONS FLEXIBILITY OF NANOFLUIDS

Basically Nanofluids are seen to be used as either for direct cooling or for providing lubrication in various industrial applications. Some of their applications are as follows:

1.2.1 Refrigeration Industry

Feasibility of nanorefrigerant in all the refrigeration system has become a big word of mouth for the refrigeration and air conditioning industries .A lot of research is ongoing in this specific area. Their pros are now felt but they still are not in commercial use.

1.2.2 HVAC industry

Application of nanofluids in buildings have also great potential since increase in energy efficiency is realized without much increase in pumping power, this application can save energy and can also provide various environmental benefits. But again it is not in commercial use and the research is still ongoing.

1.2.3 Food processing Industry

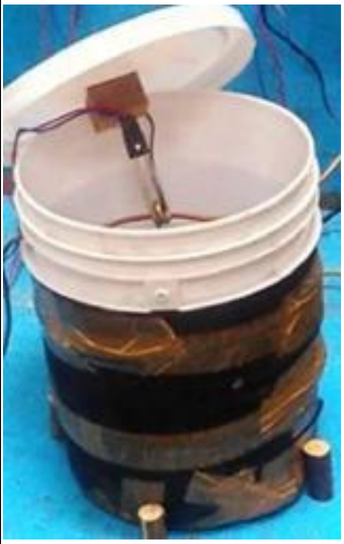
High cooling capacity is required in food processing industries to preserve the processed food. This cannot be simply achieved through present coolants, the use of nanoparticles can definitely enhance the heat transfer rate and therefore is of utmost applicable in this industry as well.

1.2.4 Enhancing Lubrication Capacity

Normal lubricants can solve the purpose of lubrication, but it becomes difficult for these conventional lubricants when the need of excessive lubrication comes into picture, it can be the case where the system is undergoing through high contact pressure and have to sustain high temperature loads, For this condition it is seen that lubricants when added with some special solid particles i.e. nano size metal particles since they have more heat dissipation properties, they are also easy to disperse, and therefore there heat carrying capacity is also very high as compared to conventional ones with other lubricating property same.

1.3 DESCRIPTION AND IMAGE OF MAJOR COMPONENTS WITH THEIR SPECIFICATION

COMPONENT NAME	SPECIFICATION	DESCRIPTION	IMAGE
COMPRESSOR	Capacity-410 btu/hr Motor input- 120 watt EER- 3.83 btu/w.hr Displacement- 4.6 CC Voltage- 150-260 V L.V. pickup-160 volt Oil charge- 300 CC Net weight- 7.8 kg Compressor measurement- 101.6*165	Sucks and Compresses the vapour refrigerant from the evaporator outlet and sends it to Condenser inlet. Increases the temperature and pressure of vapour refrigerant.	
CONDENSER	TYPE-Natural drought Diameter of pipe- +.00635metre Length of pipe – 08 metre Area of condenser- 0.2732 m^2 Material- Steel Capacity- 165 litres	It is a phase changing device which extracts the latent heat of refrigerant. Little temperature drop is also seen.	
HAND OPERATED EXPANSION VALVE	Diameter of valve- ½ inch Way of operation- Hand	In this device expansion process and substantial temperature drop is seen.	

EVAPORATOR	TYPE- Helical coil type copper tubes in bucket. Diameter of copper pipe- 0.00635 m Length of copper pipe- 7.62 metre Area of evaporator- 0.152 m^2 Material- Copper	It is the section where the cooling effect is produced actually.	
HIGH PRESSURE GAUGE	Pressure limits- 0-500 psi	Use to measure the pressure of refrigerant gas at compressor outlet.	
LOW PRESSURE GAUGE	Pressure limit- 0-150 psi	Use to measure the pressure of refrigerant gas at compressor inlet.	

HEATING ELEMENT	Specifications- 230V, 50 Hz A/C Power- 500 watt	Will be used to maintain evaporator temperature at desired limit.	
ENERGY METER	AC 1 Phase 2 wires static energy meter 3200 impulse/kwh Type- JBC-47 240V 50 Hz 5- 20 ampere	Will be used to measure the power consumption of Compressor and heating element	
CAN TAP VALVE	Quarter inch R134a dispensing valve DV-134	This valve will be installed in refrigerant can gas insertion pipe will be connected to it. Will help in charging the gas into the system.	
REFRIGERANT R134A CAN	Product name- R134a gas Quantity- 450 gram Company- Godrej	Refrigerant fluid which will be used in the VCRS setup.	

SUBMERSIBLE PUMP	Frequency- 50 Hz Voltage- 220 volt Current- 0.23 Ampere Power- 18 watt Follow 2000 litres/hrs (1metre high 24 litres/ min) Pumping head- 2.5 meters	Will be used to continuously stir the water in evaporator section so as to prevent water from freezing	
TEMPERATURE SENSORS	With temperature range from -50ºC to 70°C	Will be used to measure temperatures at all 4 sections of a VCRS system	
FLAIR NUT	Made up of brass	Will be used in joining some devices in VCRS setup like expansion valve, pressure gauges and shut off valve	
THREAD SEAL TAPE OR TEFLON TAPE		Will be used where the proper sealing is required and also tightens the joint so as to prevent any leakage.	

Ti0$_2$ Nanoparticle	Size- 30- 50 nm Material- Titanium di oxide	Will be inserted with primary refrigerant to increase heat dissipation rate.	

CHAPTER- 2

LITERATURE REVIEW

There has already been a plethora of research done in the field of vapour compression refrigeration system and nanofluids application on these systems and also abundance of literature has been published on this. Various Researchers have tried out numerous combinations of nanoparticles with different different refrigerants and checked out their applicability for long term uses. Some researchers had even tried out to find out the applicability of nanoparticles for enhancing lubrication capacity of conventional lubricants here special focus is on nanolubricants used for VCRS. Some of the earlier researches has been shown here. Therefore to do some new and unique an extensive is a prominent requirement. Some of the literature already published are shown here.

Rahul et al. [1]

A new type of nanofluid is being introduced by these researchers in their research work in then VCRS using R404A refrigerant using heat transfer properties in base fluids The various nanoparticle suspended into R404a used in VCR performance of nanorefrigerant is evaluated using energy exergy equations. The effect of thermal conductivity of nanorefrigerant, heat transfer enhancement factor of nanorefrigerant, convective heat transfer coefficient of nanorefrigerant as well as performance characteristic of vapour compression refrigeration system using different nanoparticles mixed in R404a have been evaluated. It was observed that the enhancement in thermal conductivity ranges from 20 to 100 %, heat transfer enhancement factor ranges 1.8 to 2.6 by using nanoparticle to be suspended into base refrigerant. The enhancement in the first law performance of VCRS ranges from 2.6 to 14.8 observed using nano refrigerant instead of pure eco-friendly R-404a refrigerant.

Kumar et al. [2]

In this paper, an experimental work was investigated on nanorefrigerant .Nano Al2O3 PAG oil was used as nanorefrigerant in R134a vapour compression refrigeration system. An experimental setup was designed and fabricated in the lab. The system performance was investigated using energy consumption test and freeze capacity test. The results indicate that Al2O3 nano refrigerant works normally and safely in the refrigeration system. The refrigeration system performance was better than pure lubricant with R134a working fluid with 10.32% less energy used with 0.2%V of the concentration used. The results indicate that heat transfer coefficient increases with the usage of nano Al2O3. Thus using Al2O3 Nanorefrigerant in refrigeration system is found to be feasible.

Mishra et al. [3]

These Researchers did the extensive research on VCRS using combination of different refrigerants with different nanoparticles and the result they founded were extremely interesting. The thermal modelling have been done for the same cooling load and same geometry parameter for all nanoparticles and refrigerant combination mixture in the vapour compression refrigeration based chiller system having two concentric tube type heat exchanger as evaporator and condenser. The experimental results are indicating the thermal conductivity, dynamic viscosity and density of Nano refrigerant (different nanoparticle i.e. Cu, Al2O3, CuO and TiO2 with eco-friendly refrigerant R134a, R407c and R404A) increased about 15 to 94 %, 20% and 12 to 34 % respectively compared to base refrigerant on the other hand specific heat of Nano refrigerant is slightly lower that the base refrigerant. Moreover Al2O3/R134a Nano refrigerant shows highest C.O.P. of 35%. R404A and R407 with different nanoparticle show enhancement in C.O.P. about 3 to 14 % and 3 to 12 % respectively.

M. Kwark et al. [4]

In their research these researchers have checked the pool boiling characteristic of low concentration nanofluids. They experimentally studied the behaviour of nanofluid over a flat heater. A layer of nanoparticle was formed on boiling the nano fluid. The study indicates the increase in critical heat flux due to transient characteristic in nucleate boiling heat transfer because of nanoparticle coating. Experiment also showed that microlayer evaporation was the prime reason of nanoparticle coating on heater surfaces. Results also indicates that optimal nano coating thickness is there up to which the critical heat flux will increase with no degrading effect in boiling heat transfer but above this thickness, any increase in critical heat flux can no longer be seen rather the degradation in boiling heat transfer could occur. Three nanoparticles (Al_2O_3, CuO, diamond) were used in this experiment with base fluid as water.

R.S. Mishra et al [5]

Exergy and Energy analysis of multi evaporators at different temperatures in vapour compression refrigeration system is been done in terms of performance parameter for thirteen different refrigerants, R507a, R125, R134a, R290, R600, R600a, R410a, R407c, R404a and R152a refrigerants. He used these refrigerants in primary circuit and TiO_2 nanoparticle mixed R718 in secondary circuit. For both the systems the numerical computations had been carried out. Results for these many refrigerants for the same nanoparticles gives the good understanding of its usage and its feasibility. Results shows that R152a on using as primary refrigerant gaves the best performance and R410a gave the worst. Also in terms of COP system with TiO_2 nanoparticle gave out the better performance as compared to system with Al_2O_3 nanoparticles.

Nilesh S. Desai et al [6]

In this work, SiO_2 nanoparticle is used in lubricant oil of compressor to enhance lubrication and thereby reducing compressor work which in turn will enhance COP. The stability of SiO_2 nanoparticle is also checked by suspending them into the oil and results found were favourable, the particles were steadily suspended in the mineral oil at a stationary condition even for a longer period of time. COP of system was also improved by 7.61%, 14.05% and 11.90% on addition of 1%, 2% and 2.5% by mass fraction of nanolubricant respectively.

Hao peng et.al. [7]

In the work of these researchers, the effect of Carbon Nano Tubes on nucleate pool boiling heat transfer characteristics of refrigerant R113 and oil mixture is been checked experimentally. Four types of CNTs have been tried out with varied outside diameter ranges from 15-80 nm size and length from 1.5-10 µm. Mass fraction of 0-30% CNT is taken in CNTs nanolubricant and around 0-5% mass fraction of CNT nanolubricant is used in oil mixture. Results of experiment revealed that the presence of CNTs in nanolubricant enhanced the heat transfer coefficient of R113-Oil mixture by 61%.Some parameters were there on which the enhancement depends such as with the decrease in CNTs outside diameter and with the increase in length the heat transfer increases. Also for the same dimensions of CNTs the increase in heat transfer coefficient occurs with the increase in mass fraction of CNTs in nanolubricant but decreases with the increase in mass fraction of CNT nanolubricant in the refrigerant oil mixture.

Yezhung Wu et.al. [8]

In this work a method is proposed to proliferate the energy efficiency of Retrofitted residential air conditioner applying HFC refrigerants. A new Mineral based nano refrigeration oil (MNRO) is been prepared and its feasibility is checked by finding out the performance of RAC. The Mineral-based Nano refrigeration oil (MNRO), formed by blending some nanoparticles ($NiFe_2O_4$) into naphthalene based oil B32 was employed in the RAC using R410a as refrigerant. The stability and solubility of this nanoparticle is been checked on using four different refrigerants R410a, R134a, R407c, R425a. The performance of RAC such as power input, energy efficiency, cooling and heating capacity etc. Experiments revealed that R410a with MNRO was working most efficiently as compare to other combinations. The cooling/heating EER of the RAC increased about 6% by replacing the Polyol-Easter oil VG 32 lubricant with MNRO.

Sheng Shan Bi et.al. [9]

Another nanorefrigerant experiment is been performed in this work. R600a TiO_2 is the nanorefrigerant on which the test has been made. The performance of the domestic refrigerator without any reconstruction done on it is measured by energy consumption and freeze capacity tests. The performance was evaluated and it was found that nanorefrigerant mixture R600a-TiO_2 with TiO_2 concentration as 0.5g/litre absorbed or used 9.6% less energy as compared to pure refrigerant R600a. This shows that this combination of nanorefrigerant can prove to be a better option in future use.

R.Saidur et.al. [10]

In this work, the transfer properties of various nanorefrigerants have been reviewed. Pumping power and pressure drop of refrigeration system has also been reported by reviewing different sources. Also the pool boiling heat transfer of CNT refrigerant has also been reported. Latest upto date information from literatures have been reviewed and presented in this paper. Results indicate that HFC 134a with TiO_2 nanoparticles mixed with mineral oil works safely and normally in the refrigeration system with enhanced performance. Results also showed that 26.1% of energy is saved when nanolubricant have been used with HFC 134a refrigerant with nanoparticle concentration of 0.1% mass fraction.

CHAPTER 3
RESEARCH GAPS AND OBJECTIVES

3.1 Research Gap or Problem Statement

Commercial Refrigerators are although giving good results but need for the improvement is always required for having the more advanced, unique, efficient and secure system. The novelty in this research work is that in addition with the pure refrigerant I am also going to use nanoparticle of metal TiO_2. Main objective of using the TiO_2 nanoparticle is to increase the heat dissipation rate of refrigerant therefore combination of the pure refrigerant R134a with nanoparticle is termed as Nano refrigerant. Therefore without having any adverse effect on environment cooling capacity of the system is increased. Although various combination of nanorefrigerants have been tried out also even the kind of nanorefrigerants which is used here has also been tried, but it was earlier used as a nanolubricant, so this time the purpose is different, it is used as nanorefrigerant and it is going to be tried out in an experimental setup not in the domestic refrigerator unlike earlier researches.

3.2 Objectives of Experiment

The main objective of this study is;

To analyse the performance of Experimental Vapour Compression Refrigeration System by introducing the nanorefrigerant (R134a+TiO_2) into the system.

3.3 Experimental Scopes

If everything goes as per the expectation then, after the completion of this research the scope of this work can be seen in various fields wherever the requirement of refrigeration is there, since the heat dissipation rate would definitely increase which at the end will result in optimum refrigeration. Some of the industries where it can be applied are as follows:

- Food Processing Industry
- Materials and Chemical Industry

- In Power Plants especially in Nuclear Power Plants where high cooling is required in reactors and cooling towers.
- Oil and Gas Industry
- In Cold Storage Plants
- In Automobile Industries for checking its use in automobile's engine cooling
- In Non-Traditional Machining Environment like refrigeration requirement in Laser Machining since high temperature generates during the machining and therefore high capacity cooling is also required.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction to Methodology

The methodology adopted to perform any experiment can be many and the results procured from that could also vary to a scale. This topic could also be performed by using different methodologies. Any experiment can generally imply these following methodologies to perform the tests and to get the result:

4.1.1 Constructing the Experimental setup

For performing the different tests in an experiment, methodology could be adopted. An experimental setup could be constructed as per the requirements for performing the same. The testing is then done in it and results are obtained. Here, for this topic also same approach or more appropriately similar methodology is adopted. Firstly, the setup of VCRS is constructed and then the nanorefrigerant testing is done to procure the result in the form of COP by doing energy tests.

4.1.2 Working or Experimenting on a commercial Model

The same tests could also be performed on a commercial model as well which is used by the world. This methodology is also used by various researchers to watch or observe the direct implication of the experiment and to check its feasibility for the future. This topic had also been performed using the same methodology earlier.

4.1.3 Using Computers for Simulation

Again it is also one of the methodology adopted by number of researchers now a days. There is no need of making any physical setup, in the computer only the virtual setup can be created and defining the conditions of inner and outer regions of the system drawn. Further the simulation can be done to perform the experiment, it is like performing the tests in the same way just the setup is virtual. The results can be procured in this also and final verdict can be made.

4.2 VCRS system construction

For performing on this very topic i.e. Experimental Investigation of Vapour Compression Refrigeration System by comparing the results procured after using pure refrigerant R134a with and without Titanium Oxide Nanoparticle, the methodology adopted was to create the experimental setup. So to make a setup the following steps were taken:

1. Firstly a full-fledged working plan is made before the construction is started. Working plan is made in the form of schematic diagram. Yes, a schematic diagram of VCRS is drawn showing system undergoing various processes and the positions of major equipments required for the system to run.
2. Secondly the list of all the components is made which will be required in the construction of VCRS setup. The components required were as follows:

Permanent components in setup:

a. Copper tubes (25 foot, quarter inch)
b. Compressor (hermetically sealed)
c. Condenser
d. Expansion valve (quarter inch)
e. Thermal Insulation
f. Energy meters (2 for heater and compressor)
h. Refrigerant gas R134a
I. Heater (to be applied in evaporator for maintaining temperature)
j. Bucket, Electrical wires for connection
k. High and Low Pressure gauges
l. Temperature sensors (5)
m. TiO_2 Nanoparticles
n. Shut off valve
o. Copper filter
p. Relay overload and electrical condenser for compressor

q. Flair Nut

Equipment & accessories required during construction of setup:

a. Brazing Gas

b. Brazing Rod

c. Brazing Gun

d. Flux for preventing oxidation

e. Can tap valve

f. Gas charging wire

g. Dead nut

e. Pin valve

f. Teflon tape

g. Insulating tape for wire insulation

3. After the components are listed and purchased, the real construction starts and it starts with the construction of base or foundation on which all the components is to be mounted. Firstly the welding of iron bars is done after they are cut in 4 equal parts to make its leg and then its frame. Then the wooden boards of appropriate sizes are fitted into iron frame and the foundation is ready.

4. All the major components of VCRS is now fitted on the foundation, those components are compressor, condenser, evaporator, expansion valve, energy meters.

5. Now, the copper coiling is done in evaporator and all copper tubes connections are made to complete the VCRS cycle via brazing them.

6. Then the pressure gauges both high and low are implied carefully in the inlet and outlet of compressor by using T joints.

7. Now the electrical connections are made i.e. energy meters are connected to the heater and compressor respectively, also switch connections are made to complete the whole electrical circuit.

8. Finally,applying all temperature sensors at all the measuring points and in this way the setup is ready to perform test.

4.3 Formula to be used

To find the COP in this experiment, energy tests were performed to calculate COP by measuring the power consumed by heater to power consumed by compressor.

$$COP = \frac{\text{kWh of power consumed by heater}}{\text{kwh of power consumed by compressor}}$$

4.4 System after Construction and Basic cycle of VCRS

(VCRS Experimental setup) *Figure 2*

The formula above will be used for comparing the results obtained firstly, by testing only with R134a and then testing with nanorefrigerants i.e. R134a+TiO_2.

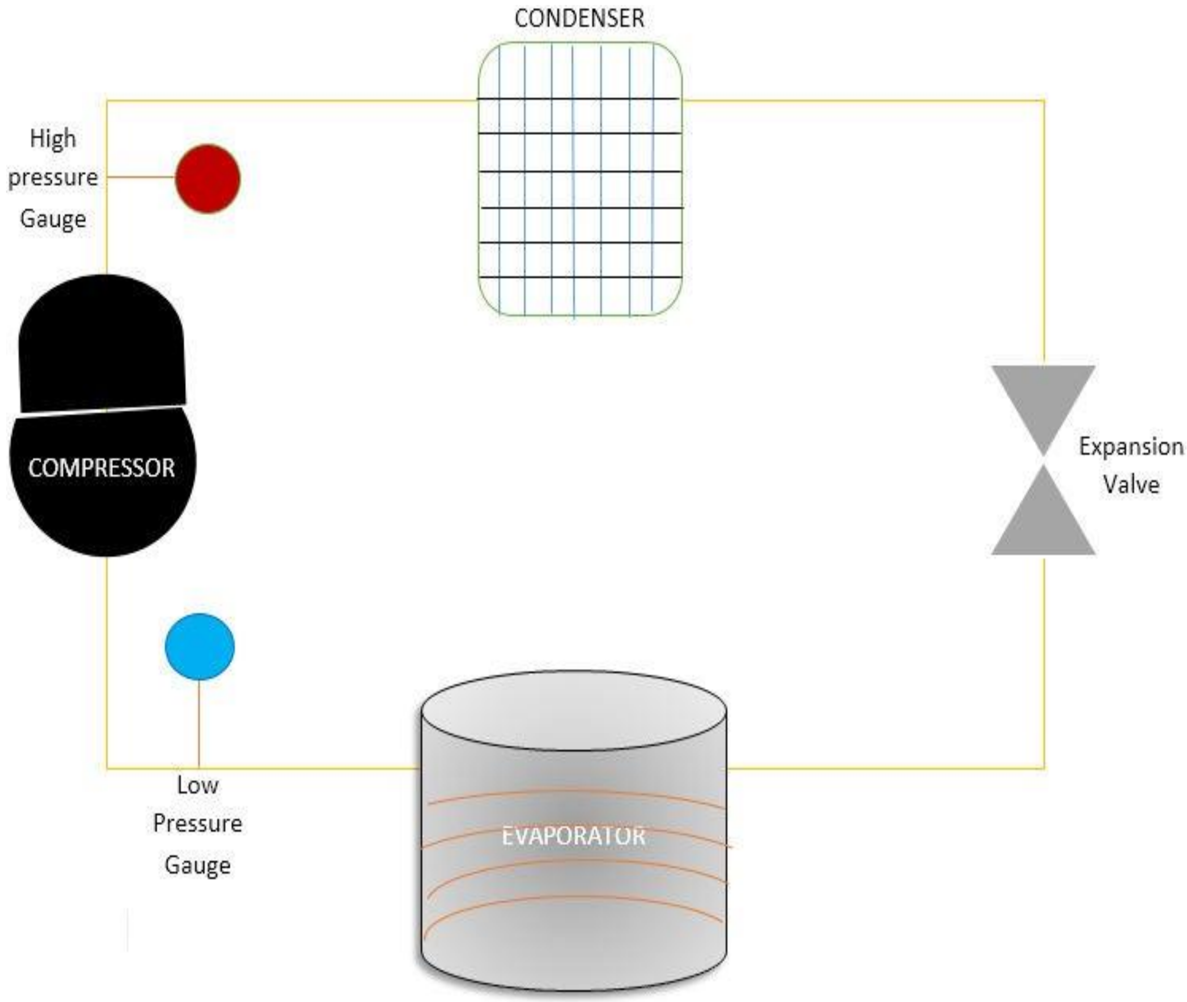

CONDENSER
High pressure Gauge
COMPRESSOR
Expansion Valve
Low Pressure Gauge
EVAPORATOR

Figure 3

CHAPTER 5
RESULTS & DISCUSSION

5.1 RESULTS PROCURED AFTER PERFORMING EXPERIMENT

After constructing and performing the experiment on the experimental setup of VCRS we procure the results as follows:

Atmospheric Temperature = 20.5°C							Refrigerant R134a = 100 gm		
T_1 (°C)	T_2 (°C)	Condenser Temperature Drop(T_1-T_2)	T_3 (°C)	T_4 (°C)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
45.9	28.1	17.8	-2.0	20	210	14	3.70	3.35	00
46.1	28.2	17.9	-2.5	20	215	12	3.73	3.38	15
46.3	28.7	17.6	-2.7	20	215	12	3.76	3.41	30
46.9	28.9	18.0	-2.8	20	225	10	3.79	3.44	45
47.5	29.4	18.1	-2.9	20	230	12	3.82	3.46	60
46.8	29.0	17.8	-3.7	20	225	10	3.85	3.48	75
47.3	29.8	17.5	-2.5	20	230	10	3.88	3.51	90
48.6	31.2	17.4	-3.8	20	225	10	3.91	3.53	105
47.7	30.1	17.6	-3.3	20	230	14	3.94	3.55	120
47.1	29.5	17.6	-2.6	20	220	10	3.97	3.57	135
48.1	30.1	18.0	-3.1	20	230	08	4.00	3.60	150
47.6	29.7	17.9	-2.8	20	230	12	4.03	3.63	165
47.9	29.9	18.0	-2.9	20	230	12	4.06	3.65	180
Difference in final and initial power consumption							4.06-3.70 = 0.36	3.65-3.35 = 0.30	

Table 1

COP = Heat Consumed by Evaporator/Power consumed by Compressor
= (3.65-3.35) / (4.06-3.70) = 0.30 / 0.36 = 0.833

Atmospheric Temperature = 20.5°C					Refrigerant R134a = 100 gm				
T_1 (ºC)	T_2 (ºC)	Condenser Temperature Drop(T_1-T_2)	T_3 (ºC)	T_4 (ºC)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
48.1	30.5	17.6	-2.3	25	215	12	4.13	3.65	00
47.9	30.2	17.7	-2.2	25	225	10	4.16	3.68	15
47.8	29.9	17.9	-2.2	25	230	12	4.19	3.71	30
47.4	29.4	18.0	-2.6	25	230	10	4.22	3.74	45
47.1	29.0	17.9	-2.9	25	225	10	4.25	3.78	60
46.9	28.8	18.1	-3.3	25	225	10	4.28	3.82	75
48.4	30.4	18.0	-2.8	25	230	10	4.31	3.86	90
46.7	28.9	17.8	-3.5	25	225	10	4.34	3.90	105
47.7	29.8	17.9	-2.3	25	230	14	4.37	3.93	120
47.1	29.0	18.1	-2.1	25	220	10	4.40	3.96	135
47.4	29.3	18.1	-2.4	25	230	8	4.43	3.99	150
47.9	29.7	18.2	-2.3	25	230	12	4.46	4.02	165
48.0	29.7	18.3	-2.4	25	230	12	4.49	4.05	180
Difference in final and initial power consumption							4.49-4.13 = 0.36	4.05-3.65= 0.40	

Table 2

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (4.05-3.65) / (4.49-4.13)

= 0.40 / 0.36 = 1.111

Atmospheric Temperature = 21°C					Refrigerant R134a = 100 gm				
T_1 (ºC)	T_2 (ºC)	Condenser Temperature Drop (T_1-T_2)	T_3 (ºC)	T_4 (ºC)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
46.0	28.0	18.0	0.9	30	195	18	4.61	4.05	00
47.5	29.6	17.9	0.6	30	200	20	4.64	4.08	15
48.2	30.2	18.0	0.2	30	210	20	4.67	4.11	30
47.4	29.3	18.1	-0.9	30	210	18	4.70	4.15	45
47.9	29.7	18.2	-1.1	30	210	18	4.73	4.19	60
47.4	29.2	18.2	-1.6	30	215	16	4.76	4.23	75
47.5	29.4	18.1	-2.1	30	215	17	4.79	4.27	90
47.7	29.4	18.3	-2.5	30	215	16	4.82	4.31	105
47.6	29.2	18.4	-2.4	30	210	18	4.85	4.35	120
47.5	28.9	18.6	-2.4	30	215	16	4.88	4.38	135
47.6	29.2	18.4	-2.2	30	215	18	4.91	4.41	150
47.5	29.0	18.5	-2.3	30	215	18	4.94	4.45	165
47.6	29.1	18.5	-2.3	30	215	17	4.97	4.48	180
Difference in final and initial power consumption							4.97-4.61 = 0.36	4.48-4.05 =0.43	

Table 3

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (4.48-4.05) / (4.97-4.61)

= 0.43 / 0.36 = 1.194

Atmospheric Temperature = 22°C					Nanoparticle Weight TiO_2(0.2 gm) + Refrigerant R134a(100 gm)				
T_1 (°C)	T_2 (°C)	Condenser Temperature Drop(T_1-T_2)	T_3 (°C)	T_4 (°C)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
48.2	29.6	18.6	-1.9	20	240	16	5.00	4.48	00
47.7	29.2	18.5	-2.4	20	240	14	5.03	4.51	15
47.9	29.5	18.4	-1.7	20	230	14	5.06	4.53	30
48.1	29.6	18.5	-1.8	20	230	16	5.09	4.55	45
48.2	29.5	18.7	-2.0	20	235	12	5.12	4.58	60
47.7	28.9	18.8	-2.1	20	235	14	5.15	4.61	75
48.3	29.7	18.6	-2.1	20	235	14	5.18	4.64	90
48.2	29.6	18.6	-2.2	20	235	14	5.21	4.66	105
47.5	28.6	18.9	-2.0	20	230	12	5.24	4.68	120
47.6	28.8	18.8	-2.1	20	230	12	5.27	4.71	135
47.9	28.9	19.0	-2.3	20	230	14	5.30	4.74	150
47.6	28.8	18.8	-2.1	20	225	14	5.33	4.77	165
47.7	28.8	18.9	-2.2	20	230	14	5.36	4.80	180
Difference in final and initial power consumption							5.36-5.00 = 0.36	4.80-4.48 =0.32	

Table 4

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (4.80-4.48) / (5.36-5.00)

= 0.32 / 0.36 = 0.888

Atmospheric Temperature = 23°C				Nanoparticle Weight TiO_2(0.2 gm) + Refrigerant R134a(100 gm)					
T_1 (ºC)	T_2 (ºC)	Condenser Temperature Drop(T_1-T_2)	T_3 (ºC)	T_4 (ºC)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
47.2	28.4	18.8	-2.1	25	210	10	5.36	4.80	00
47.4	28.7	18.7	-1.9	25	215	12	5.39	4.84	15
47.7	28.8	18.9	-2.2	25	220	14	5.42	4.88	30
47.9	28.8	19.1	-2.3	25	225	14	5.45	4.92	45
47.8	28.6	19.2	-2.2	25	220	14	5.48	4.96	60
47.7	28.7	19.0	-2.1	25	215	12	5.51	4.99	75
47.8	28.7	19.1	-2.1	25	220	14	5.54	5.02	90
47.8	28.6	19.2	-2.1	25	220	14	5.57	5.05	105
47.9	28.6	19.3	-2.2	25	220	12	5.60	5.08	120
48.0	28.8	19.2	-2.4	25	225	14	5.63	5.12	135
48.1	28.7	19.4	-2.4	25	225	16	5.66	5.16	150
47.9	28.6	19.3	-2.2	25	220	14	5.69	5.19	165
47.9	28.5	19.4	-2.2	25	220	14	5.72	5.23	180
Difference in final and initial power consumption							5.72-5.36 = 0.36	5.23-4.80 =0.43	

Table 5

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (5.23-4.80) / (5.72-5.36)

= 0.43 / 0.36 = 1.194

Atmospheric Temperature = 23°C				Nanoparticle Weight TiO_2 (0.2 gm + Refrigerant R134a (100 gm)					
T_1 (°C)	T_2 (°C)	Condenser Temperature Drop(T_1-T_2)	T_3 (°C)	T_4 (°C)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
47.2	28.1	19.1	-1.4	30	220	16	5.81	5.23	00
47.4	28.2	19.2	-1.5	30	225	16	5.84	5.27	15
47.7	28.6	19.1	-1.6	30	225	16	5.87	5.31	30
47.9	28.7	19.2	-1.7	30	225	16	5.90	5.35	45
47.8	28.5	19.3	-2.1	30	220	14	5.93	5.39	60
47.7	28.3	19.4	-2.1	30	220	14	5.96	5.43	75
47.8	28.2	19.6	-2.0	30	220	16	5.99	5.46	90
47.8	28.3	19.5	-2.2	30	220	14	6.02	5.50	105
47.9	28.3	19.6	-2.4	30	215	14	6.05	5.54	120
48.0	28.3	19.7	-2.5	30	215	12	6.08	5.58	135
48.1	28.3	19.8	-2.4	30	215	12	6.11	5.62	150
47.9	28.0	19.9	-2.3	30	215	14	6.14	5.65	165
47.9	28.0	19.9	-2.1	30	220	14	6.17	5.68	180
Difference in final and initial power consumption							6.17-5.81 = 0.36	5.68-5.23 =0.45	

Table 6

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (5.68-5.23) / (6.17-5.81)

= 0.45 / 0.36 = 1.250

Atmospheric Temperature = 23.5 °C			Nanoparticle Weight (0.4gm) + Refrigerant R134a (100 gm)						
T_1 (°C)	T_2 (°C)	Condenser Temperature Drop(T_1-T_2)	T_3 (°C)	T_4 (°C)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
46.8	27.0	19.8	-1.4	20	215	10	6.31	5.68	00
47.1	27.2	19.9	-2.0	20	220	12	6.34	5.71	15
47.2	27.5	19.7	-2.1	20	220	12	6.37	5.74	30
47.0	26.9	20.1	-2.0	20	220	12	6.40	5.77	45
47.1	26.9	20.2	-2.0	20	220	12	6.43	5.79	60
47.6	27.1	20.5	-2.2	20	225	14	6.46	5.81	75
47.9	28.0	19.9	-2.3	20	225	14	6.49	5.84	90
48.1	28.0	20.1	-2.4	20	230	16	6.52	5.87	105
47.9	28.2	19.7	-2.2	20	230	16	6.55	5.90	120
47.8	28.0	19.8	-2.1	20	230	16	6.58	5.93	135
48.0	28.3	19.7	-2.2	20	225	14	6.61	5.96	150
48.1	28.2	19.9	-2.3	20	225	12	6.64	5.99	165
47.9	28.1	19.8	-2.2	20	220	12	6.67	6.02	180
Difference in final and initial power consumption							6.67-6.31 = 0.36	6.02-5.68 =0.34	

Table 7

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (6.02-5.68) / (6.67-6.31)

= 0.34 / 0.36 = 0.944

Atmospheric Temperature = 23.5 °C				Nanoparticle Weight (0.4gm) + Refrigerant R134a (100 gm)					
T_1 (ºC)	T_2 (ºC)	Condenser Temperature Drop(T_1-T_2)	T_3 (ºC)	T_4 (ºC)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
46.5	26.1	20.4	-1.3	25	200	10	6.79	6.02	00
46.8	26.5	20.3	-1.5	25	205	10	6.82	6.06	15
47.0	26.5	20.5	-1.7	25	210	12	6.85	6.10	30
47.1	26.5	20.6	-1.8	25	210	12	6.88	6.14	45
47.2	26.4	20.8	-1.8	25	210	12	6.91	6.17	60
47.2	26.5	20.7	-1.9	25	215	12	6.94	6.20	75
47.3	26.5	20.8	-2.0	25	220	12	6.97	6.23	90
47.6	26.7	20.9	-2.2	25	220	14	7.00	6.27	105
47.7	26.8	20.9	-2.5	25	220	14	7.03	6.31	120
47.5	26.5	21.0	-2.3	25	220	14	7.06	6.34	135
47.6	26.4	21.2	-2.2	25	215	12	7.09	6.38	150
47.8	26.7	21.1	-2.4	25	215	14	7.12	6.42	165
47.9	26.7	21.2	-2.2	25	220	14	7.15	6.46	180
Difference in final and initial power consumption							7.15-6.79 = 0.36 kw	6.46-6.02 =0.44 kw	

Table 8

COP = Heat Consumed by Evaporator/Power consumed by Compressor
= (6.46-6.02) / (7.15-6.79)
= 0.44 / 0.36 = 1.2307

Atmospheric Temperature = 24.0 °C			Nanoparticle Weight (0.4gm) + Refrigerant R134a (100 gm)						
T_1 (°C)	T_2 (°C)	Condenser Temperature Drop(T_1-T_2)	T_3 (°C)	T_4 (°C)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
46.3	25.5	20.8	-0.9	30	205	14	7.26	6.46	00
46.6	25.7	20.9	-1.0	30	210	14	7.29	6.50	15
46.8	25.8	21.0	-1.1	30	210	12	7.32	6.54	30
47.1	26.2	20.9	-1.3	30	215	12	7.35	6.58	45
47.4	26.4	21.0	-1.4	30	220	12	7.38	6.62	60
47.5	26.4	21.1	-1.4	30	220	12	7.41	6.66	75
47.7	26.5	21.2	-1.5	30	215	14	7.44	6.70	90
47.6	26.2	21.4	-1.4	30	220	12	7.47	6.74	105
48.2	26.9	21.3	-2.0	30	230	16	7.50	6.78	120
48.1	26.7	21.4	-2.0	30	225	14	7.53	6.81	135
48.6	27.1	21.5	-2.5	30	230	16	7.56	6.85	150
48.5	26.9	21.6	-2.4	30	225	14	7.59	6.89	165
48.3	26.7	21.6	-2.2	30	225	14	7.62	6.93	180
Difference in final and initial power consumption							7.62-7.26 = 0.36	6.93-6.46 =0.47	

Table 9

COP = Heat Consumed by Evaporator/Power consumed by Compressor
= (6.93-6.46) / (7.62-7.26)
= 0.47 / 0.36 = 1.305

Atmospheric Temperature = 20°C			Nanoparticle Weight (0.6 gm) + Refrigerant R134a (100 gm)						
T_1 (ºC)	T_2 (ºC)	Condenser Temperature Drop(T_1-T_2)	T_3 (ºC)	T_4 (ºC)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
47.3	26.1	21.2	-1.6	20	220	10	7.73	6.93	00
47.8	26.5	21.3	-1.8	20	225	12	7.76	6.96	15
48.3	26.8	21.5	-2.0	20	230	12	7.79	6.99	30
48.5	27.1	21.4	-2.1	20	230	10	7.82	7.02	45
48.9	27.3	21.6	-2.3	20	235	12	7.85	7.05	60
49.0	27.8	21.2	-2.3	20	235	14	7.88	7.08	75
49.1	27.8	21.3	-2.4	20	235	12	7.91	7.11	90
49.4	28.0	21.4	-2.5	20	240	12	7.94	7.14	105
49.2	27.4	21.8	-2.4	20	235	10	7.97	7.17	120
49.0	27.4	21.6	-2.2	20	230	12	8.00	7.20	135
48.8	27.1	21.7	-2.1	20	230	12	8.03	7.23	150
48.7	27.1	21.6	-2.1	20	230	12	8.06	7.26	165
48.6	26.8	21.8	-2.0	20	230	12	8.09	7.29	180
Difference in final and initial power consumption							8.09-7.73 = 0.36	7.29-6.93 =0.36	

Table 10

COP = Heat Consumed by Evaporator/Power consumed by Compressor
= (7.29-6.93) / (8.09-7.73)
= 0.36 / 0.36= 1.0

Atmospheric Temperature = 25 °C			Nanoparticle Weight (0.6 gm) + Refrigerant R134a (100 gm)						
T_1 (ºC)	T_2 (ºC)	Condenser Temperature Drop(T_1-T_2)	T_3 (ºC)	T_4 (ºC)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
46.0	23.7	22.3	-1.0	25	195	8	8.18	7.29	00
46.6	24.2	22.4	-1.2	25	210	10	8.21	7.33	15
46.9	24.6	22.3	-1.4	25	220	12	8.24	7.37	30
47.1	24.6	22.5	-1.5	25	215	14	8.27	7.41	45
47.2	24.6	22.6	-1.5	25	215	12	8.30	7.45	60
47.4	24.8	22.6	-1.6	25	215	12	8.33	7.49	75
47.6	25.1	22.5	-1.8	25	210	10	8.36	7.52	90
47.7	25.0	22.7	-1.7	25	215	10	8.39	7.55	105
47.9	25.1	22.8	-1.8	25	220	12	8.42	7.59	120
47.8	25.0	22.8	-1.5	25	220	10	8.45	7.63	135
48.0	25.1	22.9	-1.6	25	225	14	8.48	7.67	150
48.1	25.1	23.0	-1.4	25	220	12	8.51	7.71	165
48.3	25.3	23.0	-1.7	25	220	12	8.54	7.75	180
Difference in final and initial power consumption							8.54-8.18 = 0.36 kw	7.75-7.29 =0.46 kw	

Table 11

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (7.75-7.29) / (8.54-8.18)

= 0.46 / 0.36 = 1.277

Atmospheric Temperature = 30 °C			Nanoparticle Weight TiO_2(0.6 gm) + Refrigerant R134a(100 gm)						
T_1 (°C)	T_2 (°C)	Condenser Temperature Drop(T_1-T_2)	T_3 (°C)	T_4 (°C)	P_1 (psi)	P_2 (psi)	Power consumed by Compressor	Power consumed by Evaporator	Time (min)
46.4	23.8	22.6	-0.7	30	210	08	8.66	7.75	00
46.8	24.3	22.5	-1.1	30	220	12	8.69	7.79	15
46.9	24.2	22.7	-1.2	30	220	10	8.72	7.83	30
47.2	24.2	22.6	-1.4	30	225	10	8.75	7.87	45
47.4	24.7	22.7	-1.6	30	230	12	8.78	7.91	60
47.5	24.7	22.8	-1.6	30	230	12	8.81	7.95	75
47.7	24.8	22.9	-1.7	30	235	14	8.84	7.99	90
47.8	24.8	23.0	-1.8	30	235	12	8.87	8.03	105
48.0	24.9	23.1	-2.0	30	235	14	8.90	8.07	120
48.2	24.9	23.3	-2.1	30	240	10	8.93	8.11	135
48.3	24.9	23.4	-2.4	30	240	12	8.96	8.15	150
48.1	24.8	23.3	-2.3	30	235	14	8.99	8.19	165
48.0	24.6	23.4	-2.3	30	235	12	9.02	8.23	180
Difference in final and initial power consumption							9.02-8.66 = 0.36	8.23-7.75 =0.48	

Table 12

COP = Heat Consumed by Evaporator/Power consumed by Compressor

= (8.23-7.75) / (9.02-8.66)

= 0.48 / 0.36 = 1.333

5.2 RESULTS COMPARISON

After performing the experimental study and procuring the results, now we will be comparing the results obtained by using the means of graphs and tables:

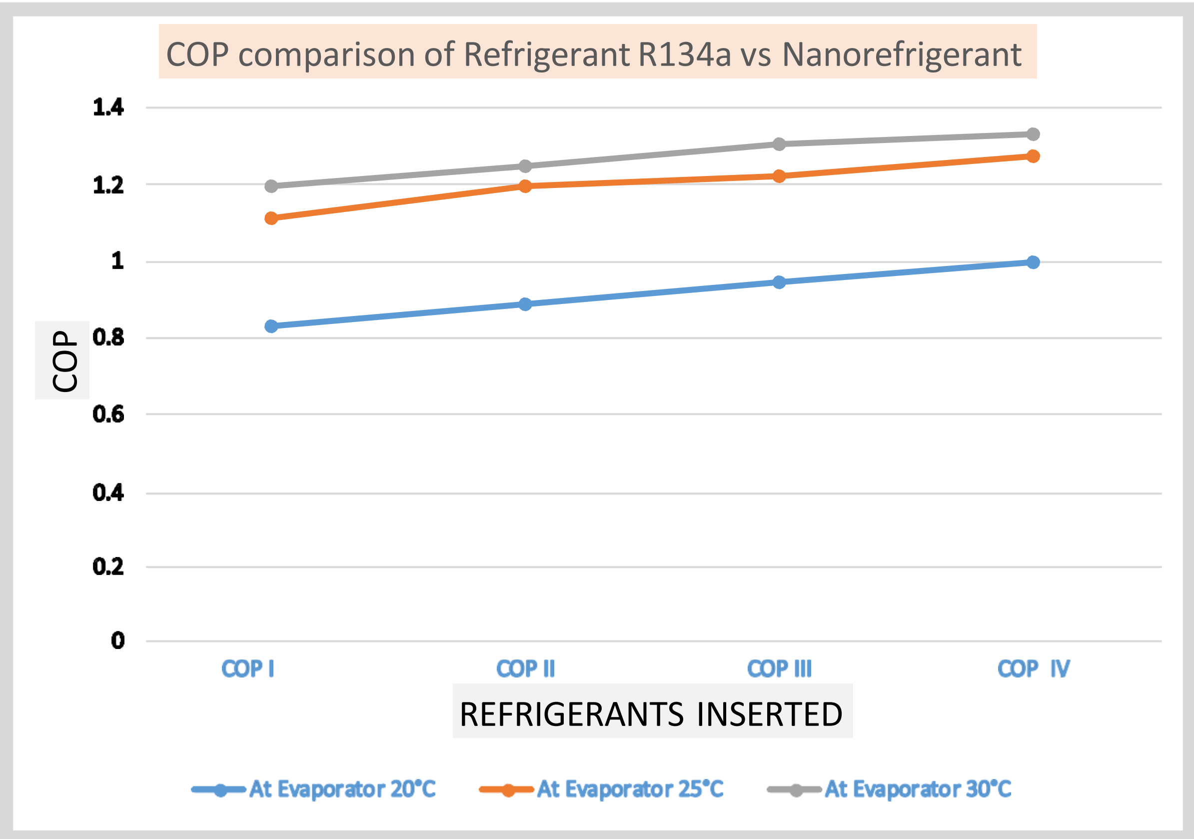
5.2.1 Comparison of Coefficient of Performance (COP)

T_4 (°C)	COP I	COP II	Percentage Improvement in COP (%)	COP III	Percentage Improvement in COP (%)	COP IV	Percentage Improvement in COP (%)
20	0.833	0.888	5.5	0.944	11.1	1.0	16.7
25	1.111	1.194	8.3	1.222	11.1	1.277	16.6
30	1.194	1.250	5.6	1.305	11.1	1.333	13.9

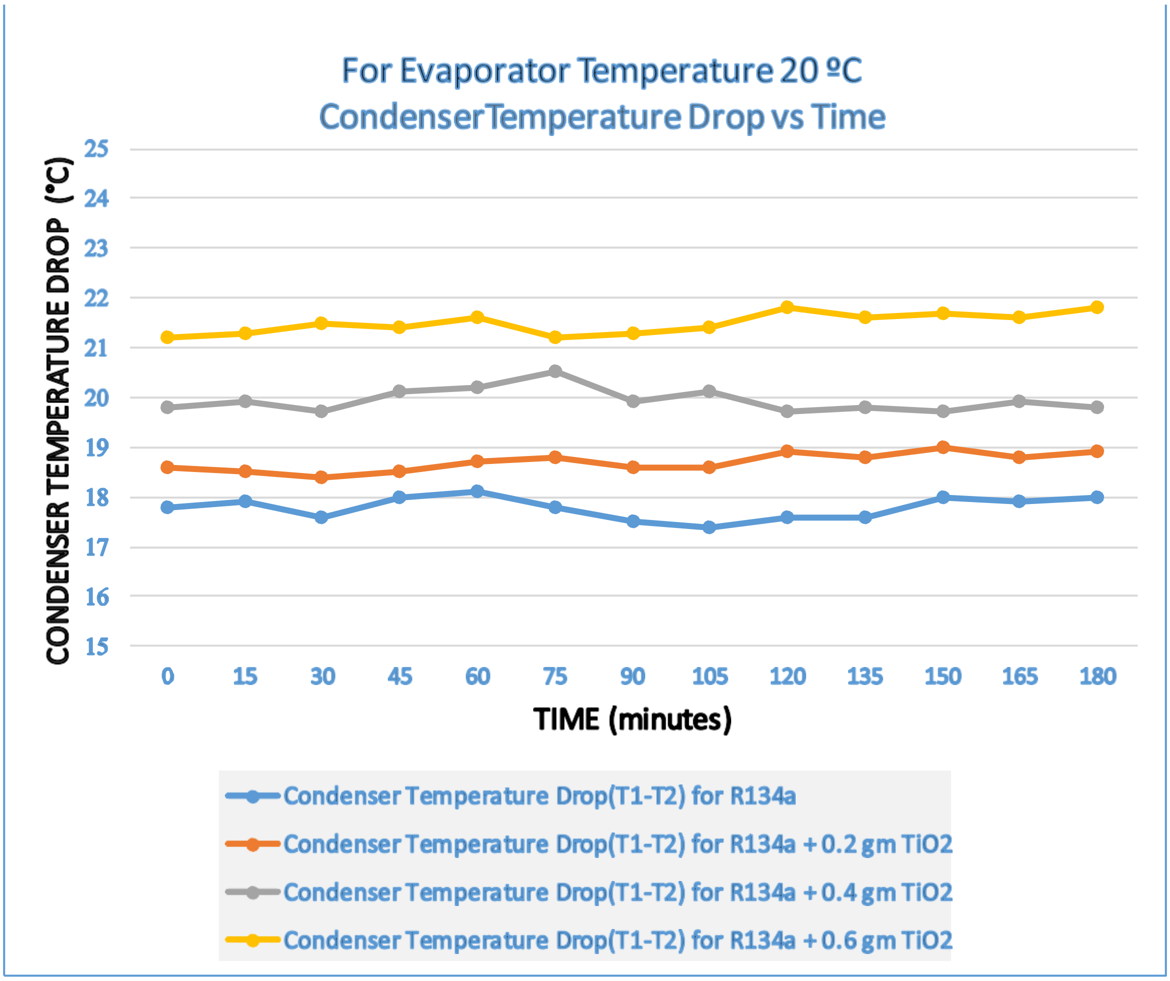
Table 13

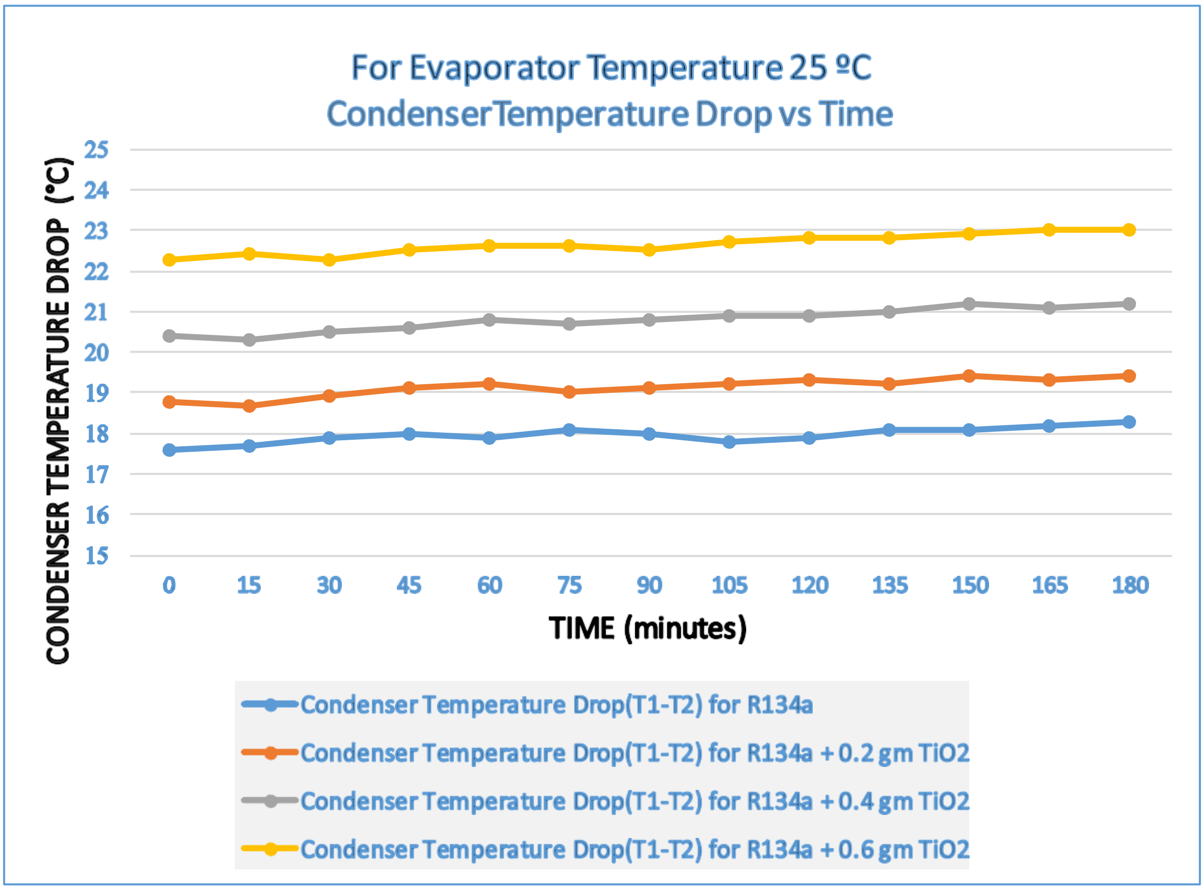
Where,

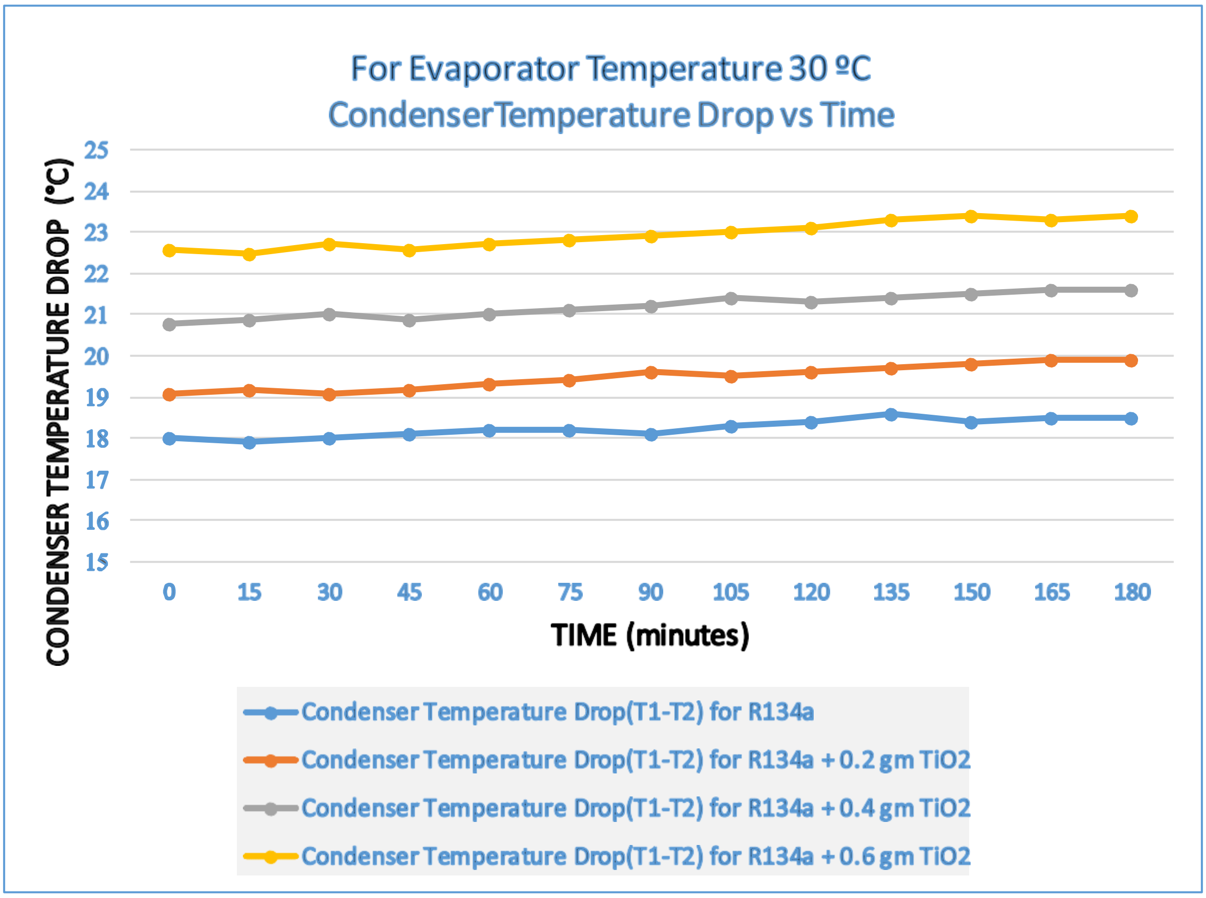
T_4 = Temperature Maintained at Evaporator Section (°C)
COP I = COP when R134a (100 gm) is inserted
COP II = COP when R134a (100 gm) + 0.2 gm TiO2 inserted
COP III = COP when R134a (100 gm) + 0.4 gm TiO2 inserted
COP IV = COP when R134a (100 gm) + 0.6 gm TiO2 inserted



5.2.2 Comparison of Condenser Temperature Drop (°C)




For Evaporator Temperature 25 ºC
CondenserTemperature Drop vs Time
CONDENSER TEMPERATURE DROP (°C)
25
24
23
22
21
20
19
18
17
16
15
0
15
30
45
60
75
90
105
120
135
150
165
180
TIME (minutes)
Condenser Temperature Drop(T1-T2) for R134a
Condenser Temperature Drop(T1-T2) for R134a +0.2 gm TiO2
Condenser Temperature Drop(T1-T2) for R134a +0.4 gm TiO2
Condenser Temperature Drop(T1-T2) for R134a +0.6 gm TiO2


For Evaporator Temperature 30 ºC
CondenserTemperature Drop vs Time
CONDENSER TEMPERATURE DROP (°C)
25
24
23
22
21
20
19
18
17
16
15
0
15
30
45
60
75
90
105
120
135
150
165
180
TIME (minutes)
Condenser Temperature Drop(T1-T2) for R134a
Condenser Temperature Drop(T1-T2) for R134a +0.2 gm TiO2
Condenser Temperature Drop(T1-T2) for R134a +0.4 gm TiO2
Condenser Temperature Drop(T1-T2) for R134a +0.6 gm TiO2

CHAPTER 6

CONCLUSION AND FUTURE SCOPES

6.1 CONCLUSION OF WHOLE STUDY

In this experimental study, another VCRS setup with unique specifications either its compressor type; evaporator shape, size, length of copper tubes used in it; diameter of copper tubes; type of condenser, number of turns in it, length of tube and capacity of that particular condenser; kind of expansion valve used was developed and therefore it was but obvious that results which was procured were also unique.

To complete the thesis and the bid to make it a success, my key role was firstly to make VCRS set up with as much perfection as possible which I did with great sincerity and care.

After the setup was prepared, the investigation was started by firstly inserting the R134a refrigerant into the system and COP of the system was calculated by using the energy consumption tests, the way by which we procured the results is very well explained in chapter 4 and chapter 5. The similar procedure was used when nanorefrigerants were used in the VCRS system and then finally the results were compared.

The thesis work's results statement and its contributions is concluded in following points:

- COP was increased when nanorefrigerants were used in the VCRS experimental setup as compared to that of only R134a refrigerants.
- Sudden COP enhancement was seen when 0.2 gram TiO_2 nanoparticles was used as compared to when 0.4 gram and 0.6 gram was inserted in which proliferation rate was not that much.
- Exactly, 11.1% improvement was seen when nanorefrigerant mixture of 0.4 gram TiO_2 was used with R134a at evaporator temperatures of 20°C, 25°C and 30°C.
- Condenser temperature drop was increased when nanorefrigerants were used and it kept on increasing when nanoparticle concentration was

increased. It was seen maximum when 0.6 gram nanoparticle was inserted with refrigerant R134a.

- Although on using nanorefrigerant mixture of 0.6 gram TiO_2 and R134a 100 gram the condenser drop was maximum but nanorefrigerant had become a bit more viscous than desired, this effect was felt and understood by the difficulty of nanorefrigerant passing the area in expansion valve, it was getting choked and to prevent it sometimes more cross-section area of expansion valve had to be opened. So, according to study this was clearly understood that there is a limit of varying the concentration of nanoparticle as the particle clogging can create difficulty in smooth functioning of the system.
- In this experiment, in using nanoparticle there is no increase or decrease in power consumption was seen, which shows that nanoparticle was completely dissolved in the refrigerant R134a.

6.2 FUTURE SCOPES

Nanotechnology is the future in the field of refrigeration in the upcoming period and therefore there is a plenty of scope of nanorefrigerants, nanolubricants and might be any new nano based technology in refrigeration and air conditioning field.

Some of the future work which is still can be done in refrigeration field using nanotechnology:

- New type of nanorefrigerants can be developed by using different nanoparticles with different sets of refrigerants and their blends.
- Practicability of nanoparticles should specially be checked for using it with Eco-friendly refrigerants who have less global warming and ozone depletion potential.
- Very less researches till date had revealed about the property variations when nanoparticles is used with any primary refrigerant, so it's an area which still require a thorough clarification.
- Although a lot research is been done on the use of nanorefrigerants but there is very few researches which has exactly revealed about the exact concentration of nanoparticles to be used with primary refrigerant so as to use it commercially.

- New kind of nanolubricant can also be developed by doing further research and thereby can reduce power consumption of compressor.

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