

# Enhancing Heat Transfer Rate Using Nano Fluids in Refrigerator

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**ABSTRACT:** Nanofluids are a fluid containing nano meter sized particles, called nanoparticles. These fluids are Suspension of nanoparticles in conventional fluids. Nanofluids have been the subject of intensive study worldwide since pioneering researchers recently discovered the anomalous thermal behavior of these fluids. The enhancement of heat transfer using nanofluids have been used as one of the passive heat transfer techniques in several heat transfer applications. Performance of the refrigeration system becomes main issue and many researches are still ongoing to evaluate and improve efficiency of the system. Refrigerator is one of the home appliances utilizing mechanical vapour compression cycle in it process. This report mainly focuses on nano particles used for enhance heat transfer in refrigerator. This article reports an experimental study on the refrigerator with R134a Refrigerant and Al<sub>2</sub>O<sub>3</sub>Nano Particles and different volume concentrations of Al<sub>2</sub>O<sub>3</sub> nanofluid. The Al<sub>2</sub>O<sub>3</sub> nanoparticles of about 30 nm diameter are used in the present study. The heat transfer coefficient increases with the increase of the volume concentration of the Al<sub>2</sub>O<sub>3</sub> nanofluid, however increasing the volume concentration cause increase in the viscosity of the nanofluid leading to increase in friction factor. The graph between time and temperature with and without nano particles shows the increase in heat transfer using nano particles. An improvement in COP and power consumption was also observed during the investigations

**KEYWORDS:** Nanofluids, VCRS Cycle, Refrigerants, Domestic Refrigerator, Al<sub>2</sub>O<sub>3</sub>, HFC.

## I. INTRODUCTION

Nanofluids are a relatively new class of fluids which consist of a base fluid with nano-sized particles (1–100 nm) suspended within them. These particles, generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer in wide application such as in heat exchanger, automotive cooling and refrigeration system. To improve thermal conductivity of a fluid, suspension of ultrafine solid particles in the fluid can be a creative idea. Different types of particles (metallic, non-metallic and polymeric) can be added into fluids to form slurries. Due to the fact that sizes of these suspended particles are in the millimetre or even micrometer scale, some serious problems such as the clogging of flow channels, erosion of pipelines and an increase in pressure drop can occur. Especially, the particles tend to settle rapidly. For that reason, though the slurries have better thermal conductivities but they are not practical. HFC134a is the most widely used alternative refrigerant in refrigeration equipment such as domestic refrigerators, chillers and automobile air conditioners.

HFC134a has been accepted as long term alternative refrigerant in many countries. Nano-particles suspended in lubricant of the compressor is found to be increasing the system efficiency and also the system works without any choking. Nano Al<sub>2</sub>O<sub>3</sub> gives better performance by returning more lubricant oil back to the compressor. Nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, nanorods, nanosheet, or droplets) in base fluids.

Nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields. For a two-phase system, there are some important issues we have to face. One of the most important issues is the stability of nanofluids, and it remains a big challenge to achieve

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desired stability of nanofluids. In this paper, we will review the new progress in the methods for preparing stable nanofluids and summarize the stability mechanisms. In recent years, nanofluids have attracted more and more attention. The main driving force for nanofluids research lies in a wide range of applications. Although some review articles involving the progress of nanofluid investigation were published in the past several years, most of the reviews are concerned of the experimental and theoretical studies of the thermo physical properties or the convective heat transfer of nanofluids.

## II. RELATED WORK

**Kuljeet Singh, Kundan Lal.[1]** carried out an investigation into the performance of a Nano refrigerant (R134a+Al<sub>2</sub>O<sub>3</sub>) based refrigeration system. It has been found out that the improvement in coefficient of performance (COP) is maximum (7.2 to 8.5%) with 0.5% Al<sub>2</sub>O<sub>3</sub> (% wt.) nanoparticles.

**N. Subramani[2]** done “ Experimental studies on a vapour compression system using nano-refrigerants”. It was found that, the R134a refrigerant and mineral oil mixture with nanoparticles worked normally (ii) Freezing capacity of the refrigeration system is higher with SUNISO 3GS + alumina nanoparticles oil mixture compared the system with POE oil (iii) The power consumption of the compressor reduces by 25% when the nano-lubricant is used instead of conventional POE oil (iv) The coefficient of performance of the refrigeration system also increases by 33% when the conventional POE oil is replaced with nano-refrigerant.

**D. Sendil Kumar[3]** Nano Al<sub>2</sub>O<sub>3</sub>-PAG oil was used as Nano refrigerant in R134a vapour compression refrigeration system and it was found that addition of nano Al<sub>2</sub>O<sub>3</sub> in to the refrigerant shows improvement in the COP of the refrigeration system. Usage for Nano refrigerant reduces the length of capillary tube and cost effective.

**Omer A. Alawi[4]** presented a comprehensive review of fundamentals, preparation and applications of nanorefrigerants. Physical properties of nano refrigerants such as density and viscosity, surface tension and specific heat have a significant effect on nucleate pool boiling, convective flow boiling and condensation. He concluded that adding nanoparticles to the refrigerant enhanced the heat transfer and that the heat transfer coefficient increased with increased nanoparticle mass fraction.

**Adnan M. Hussein [5]** “The Effect of Nanofluid Volume Concentration on Heat Transfer and Friction Factor inside a Horizontal Tube” Data measured showed that thermal conductivity and viscosity increase with increasing the volume concentration of nanofluids with maximum deviation 19% and 6%, respectively. Simulation results concluded that the friction factor and Nusselt number increase with increasing the volume concentration.

**Faris Mohammed Ali et. al [6]** “Study of the effect of particles size and volume fraction concentration on the thermal conductivity and thermal diffusivity of Al<sub>2</sub>O<sub>3</sub> nanofluids. The results show that, the thermal conductivity and thermal diffusivity enhancement of nanofluids increases as the particle size increases.

**S. Zeinali Heris et. al [7]** Experiments show that considerable enhancement of heat transfer coefficient is achieved and this enhancement is up to 27.6% at 2.5% volume fraction of nanoparticles comparing to the base fluid (water), also it has been noticed that convective heat transfer coefficient increases with the increment of nanoparticles concentration in nanofluid especially at high flow rates. The decrement of wall temperature observed using nanofluid.

**Azari et. al [8]** Experimental and numerical Experimental and simulation results showed that the thermal performance of nanofluids is higher than that of the base fluid and the heat transfer enhancement increases with the particle volume concentration and Reynolds number.

**Hassanain Ghani Hameed et. al [9]** Numerical Results found the nanoparticles within the liquid enhance the thermal performance of the heat pipe by reducing the thermal resistance and temperature difference by 0.168 K/W and 5.06 K respectively. While increasing the maximum heat load and the capillary pressure by 96 W and 192.46 Pa respectively.

**Layth W. Ismael et. al [10]** The experimental results emphasized the enhancement of the thermal conductivity due to the nanoparticles presence in the fluid greater than microfluids, also shown the effect of the particle size and concentration on the thermal conductivity. It has been recognized that the addition of highly conductive particles can significantly increase the thermal conductivity of heat – transfer fluids. Particles in the micro and nano – size range have attracted the most interest because of their enhanced stability against sedimentation and, as a result, reduction in potential for clogging a flow system.

### III. PROPOSED TECHNIQUE

A refrigeration system is a combination of components and equipment connected in a sequential order to produce the refrigeration effect. In real applications, vapour-compression refrigeration systems are the most commonly used in refrigeration systems. Refrigeration deals with the transfer of heat from a low temperature level at the heat source to a high temperature level at the heat sink by using a low boiling refrigerant.

#### Vapour compression refrigeration system

As mentioned, vapour compression refrigeration systems are the most commonly used among all refrigeration systems. As the name implies, these systems belong to the general class of vapour cycles, wherein the working fluid (refrigerant) undergoes phase change at least during one process. In a vapour compression refrigeration system, refrigeration is obtained as the refrigerant evaporates at low temperatures. The input to the system is in the form of mechanical energy required to run the compressor. Hence these systems are also called as mechanical refrigeration systems. Vapour compression refrigeration systems are available to suit almost all applications with the refrigeration capacities ranging from few Watts to few megawatts. A wide variety of refrigerants can be used in these systems to suit different applications, capacities etc. The actual vapour compression cycle is based on Evans-Perkins cycle, which is also called as reverse Rankine cycle. Before the actual cycle is discussed and analysed, it is essential to find the upper limit of performance of vapour compression cycles. This limit is set by a completely reversible cycle.

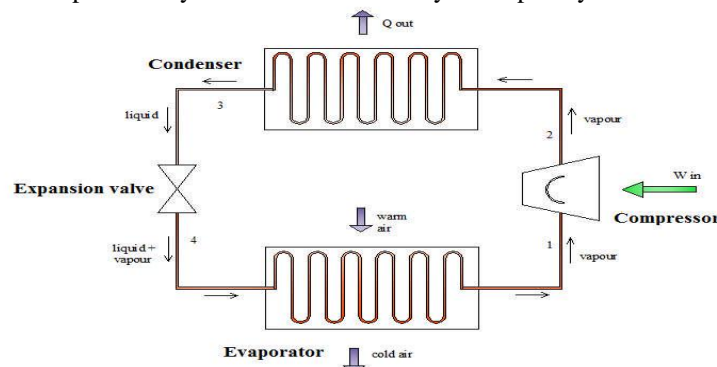


Fig.1 : Standard vapour compression refrigeration cycle

The standard vapour compression refrigeration system consists of a refrigerant in a closed circuit comprising a compressor, a condenser, an expansion device, an evaporator and interconnecting pipeline. In the condenser, compressed refrigerant vapour at high pressure is condensed at high temperature by heat transfer to the surroundings. The high-pressure refrigerant liquid is reduced to a low pressure at the expansion valve. At low pressure, the refrigerant will evaporate at a low temperature enabling it to extract heat from the substance to be cooled. To complete the cycle, the low pressure refrigerant vapour exiting the evaporator is compressed to high pressure by the compressor. The total heat rejected in the condenser is the sum of the heat extracted plus the compressor energy use.

#### ALUMINUM OXIDE (Al<sub>2</sub>O<sub>3</sub>) NANOPARTICLES

Nanoparticles are being used more and more often in research and in industry, due to their enhanced properties compared to bulk materials. The benefits of nanoparticles can include increased electrical conductivity, toughness and ductility, and increased hardness and strength of metals and alloys. This article discusses the properties and applications of aluminium oxide nanoparticles. Aluminium is a Block P, Period 3 element, while oxygen is a Block P, Period 2 element. The morphology of aluminum oxide nanoparticles is spherical, and they appear as a white powder. Aluminum oxide nanoparticles (both liquid and solid forms) are graded as highly flammable and an irritant that can cause serious eye and respiratory irritation

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Table1. Chemical Properties of Al <sub>2</sub> O <sub>3</sub>	
Chemical symbol	Al <sub>2</sub> O <sub>3</sub>
Group	Aluminum 13, Oxygen 16
Electronic configuration	Aluminium [Ne]3s <sup>2</sup> 3p <sup>1</sup> Oxygen [He] 2s <sup>2</sup> 2p <sup>4</sup>

The chemical formula combines two aluminium atoms to three oxygen atoms, which is expressed as Al<sub>2</sub>O<sub>3</sub>. It is an electrical resistor, unlike its cousin aluminium. The resistance level changes with the purity of the material. Aluminium oxide does not react readily with most materials, but it is highly reactive to chlorine trifluoride and ethylene oxide. Mixing aluminium oxide with either of these chemicals causes a fire.

Table2. Chemical Composition of Al <sub>2</sub> O <sub>3</sub>	
Element	Content (%)
Aluminum	52.92
Oxygen	47.04

Alumina. Alumina, also called aluminium **oxide**, synthetically produced aluminium **oxide**, Al<sub>2</sub>O<sub>3</sub>, a white or nearly colourless crystalline substance that is used as a starting material for the smelting of aluminum metal. It is commonly called **alumina** and may also be called **aloxide**, **aloxite**, or **alundum** depending on particular forms or applications. It occurs naturally in its crystalline polymorphic phase  $\alpha$ -Al<sub>2</sub>O<sub>3</sub> as the mineral corundum, varieties of which form the precious gemstones ruby and sapphire. Al<sub>2</sub>O<sub>3</sub> is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point

Table3. Physical Properties of Al <sub>2</sub> O <sub>3</sub>		
Properties	Metric	Imperial
Density	3.9 g/cm <sup>3</sup>	0.140 lb/in <sup>3</sup>
Molar mass	101.96 g/mol	-

Aluminum oxide is a very hard material, almost to the level of diamonds, so it has excellent wear resistance properties. It has high corrosion endurance and high temperature stability, low thermal expansion and a favourable stiffness-to-weight ratio. Since aluminum oxide has an excellent electrical resistor, it is often used in capacitors as the dielectric, the part keeping charges in the device separated..

Table4. Thermal Properties of Al <sub>2</sub> O <sub>3</sub>		
Properties	Metric	Imperial
Melting point	2040°C	3704°F
Boiling point	2977°C	5391°F

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Aluminum oxide does not dissolve in water and has a very high melting point of 2,000 C or about 3,600 F. Its boiling point is an extremely high 5,400 F.

Thermal Conductivity @ 20 C : 28 - 35 W/m-K

Thermal Expansivity, 20 - 1000 C :  $8.0 \times 10^{-6}$  m/m-K

Upper Continuous Use Temperature : 1800 C

## IV. EXPERIMENTAL SETUP AND RESULTS

The experimental consists of compressor, condenser, expansion device and an evaporator. Capillary tube is used as an expansion device. Service ports are provided at the compressor for charging the refrigerant. The mass flow rate is measured with the help of flow meter fitted in the line between expansion device and drier unit. All the main components are fitted in Refrigerator Cabin.

Refrigerant	R134a
Gas charged	150gm
Gross capacity	220L
Compressor	Reciprocating

Table 5. Refrigeration system specifications

### Instrumentation

The temperature at deep freezer measured using Digital thermometer. The pressure at compressor suction, discharge, are measured with the help of pressure gauges. The power consumption of the system was measured by a digital Clamp meter. Table6. Summarized the characteristics of the instrumentation.

Variable	Device	Range
Temperature	Pt100 PID controller	-50 to 199°C
Pressure	Pressure Gauge	0-10 bar
Power	Clamp meter	5-20A

Table 6. Measurement meter Equipment

### Preparation Methods for Nanofluids

Various methods have been tried to produce different kinds of nanoparticles and nano suspensions. There are two primary methods to prepare nanofluids: A two-step method in which nanoparticles or nanotubes are first produced as a dry powder. The resulting nano particles are then dispersed into a fluid in a second step and Single-step nanofluid processing methods have also been developed.

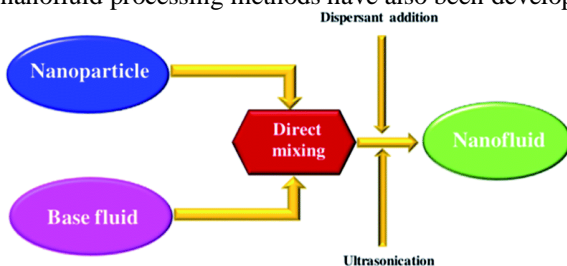


Fig.2. Schematic of two step method

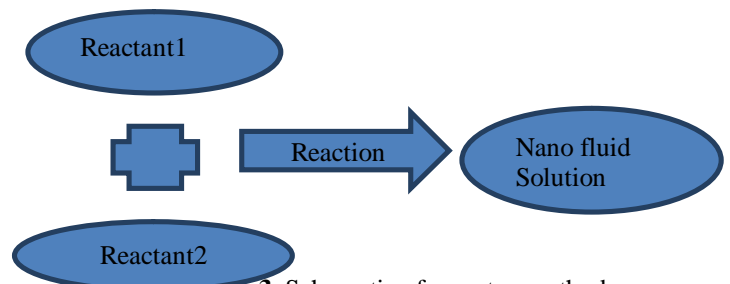


Fig .3. Schematic of one step method

Two-Step Method is the most widely used for preparing nanofluids. The nano-sized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-

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shear mixing, homogenizing, and ball milling. one-step methods have been developed for preparing nanofluids. Using this method including direct evaporation, condensation, chemical vapour condensation, and single-step chemical synthesis.

### Nano- Refrigerant Concentration

Nano-Refrigerant with 0.2% concentration of Al<sub>2</sub>O<sub>3</sub> in the refrigerant R134a is prepared and tested in the setup.

### Charging of the set up

The fabricated experimental setup was filled with N<sub>2</sub> gas at a pressure of 5 bar to 7 bar and this pressure is maintained for 45 minutes. Thus the system was ensured for no leakages. The system was evacuated by removing N<sub>2</sub> gas. A vacuum pump was connected to the port provided in the compressor and the system was completely evacuated for the removal of any impurities. This process was carried out for all the trials.

Through the service ports nano particles (30nm) Al<sub>2</sub>O<sub>3</sub> was carefully added to the system. Precision electronic balance with accuracy  $\pm 1\%$  was used to charge a mass of 150 gm. into the system. Every time the system was allowed to stabilize for 15 min.

## RESULTS AND DISCUSSIONS

COP is defined as the ratio of refrigeration effect and work input to the system. COP is highly influenced by operating conditions, especially ambient temperature and relative temperatures between sink and system. Here in this experimental study actual COP of refrigeration system has been investigated.

### Temperature Readings with and without Nano particles

s.no	Time(hr))	p1(psi)	p2(psi)	Temp (R134a) (°c)	Temp(R134a+20 gm of Al <sub>2</sub> O <sub>3</sub> ) (°c)	Temp(R134a+30 gm of Al <sub>2</sub> O <sub>3</sub> ) (°c)	Temp(R134a+50 gm of Al <sub>2</sub> O <sub>3</sub> ) (°c)
1	3.00	14	241	10	5	5	5
2	3.20	11	256	-1	-6	-7	-8
3	3.40	9	246	-4	-7	-8	-10
4	4.00	9	246	-5	-8	-9	-
5	4.20	8	240	-6	-8	-10	-

Table 7. Temperature at salient points

The temperature of 10 °c can be obtained with pure R134a Refrigerant only within 3hrs and -6 °c can be obtained with in 4.20 hrs. And suction, discharge pressure readings are taken. Simultaneously readings are taken by adding nanoparticles of AL<sub>2</sub>O<sub>3</sub>. By increasing the nanoparticles to the system, the fast heat transfer can takes place.



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## Graphs between Time VS Temperature

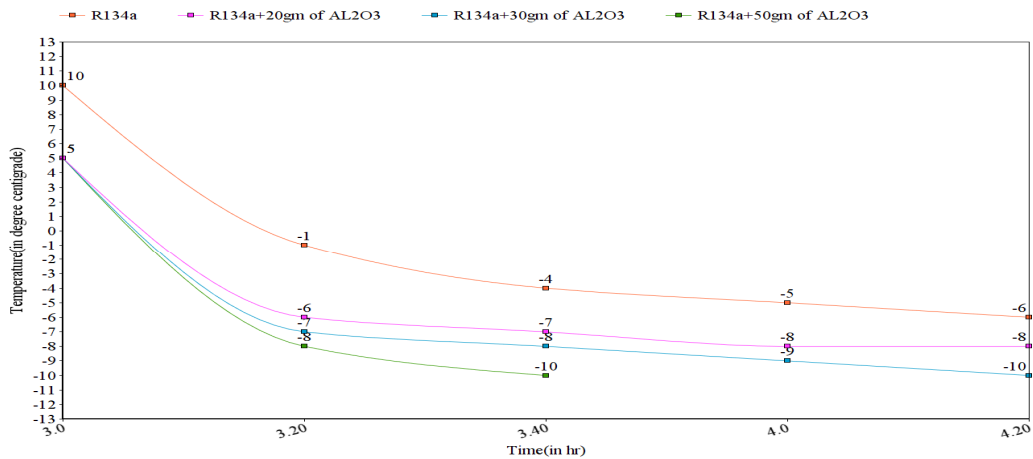


Fig 4 : Graph between Time VS Temperature

The cooling load temperature –time analysis for pure refrigerant R134a, refrigerant R134a +30gm Al<sub>2</sub>O<sub>3</sub> and refrigerant R134a + 50 gm Al<sub>2</sub>O<sub>3</sub> at ambient temperature 5°C to -10°C. In this study it is found that pure refrigerant R134a takes 1 hour 40 minutes for temperature drop from 5°C to -10°C, while nano refrigerant R134a+ 30 gm Al<sub>2</sub>O<sub>3</sub> takes 1-hour 30 minutes. While nano refrigerant R134a +50 gm Al<sub>2</sub>O<sub>3</sub> takes 1 hour for temperature drop from 5°C to -10°C.

## Graphs between Pressure VS Al<sub>2</sub>O<sub>3</sub> concentrations

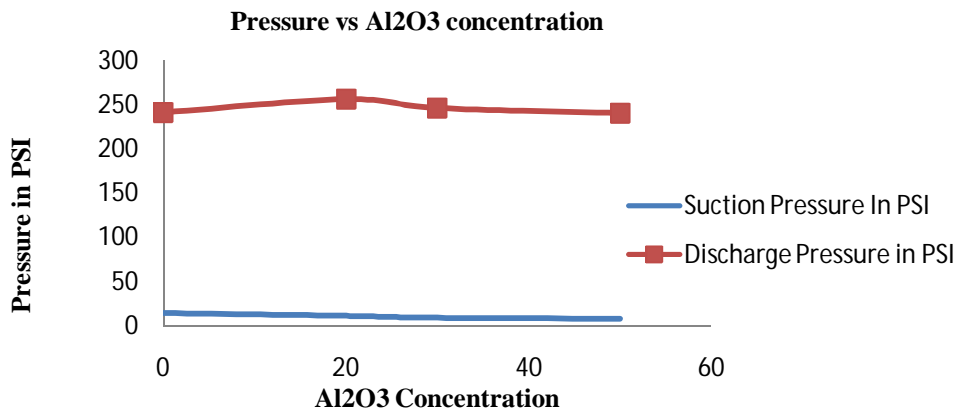


Fig 4 : Graph between Pressure VS Al<sub>2</sub>O<sub>3</sub>

Fig4. Shows that the suction and discharge pressure of compressor with respect to Al<sub>2</sub>O<sub>3</sub> concentration. The discharge pressure can be increased with 20gm of Al<sub>2</sub>O<sub>3</sub> Concentration. While increasing the concentration the suction and discharge pressures are decreased.

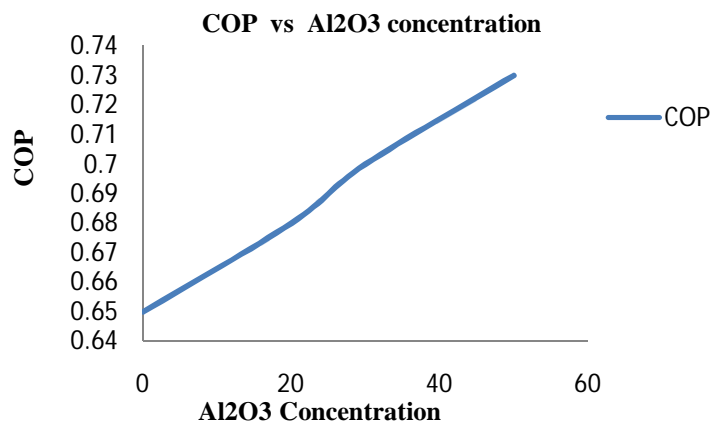
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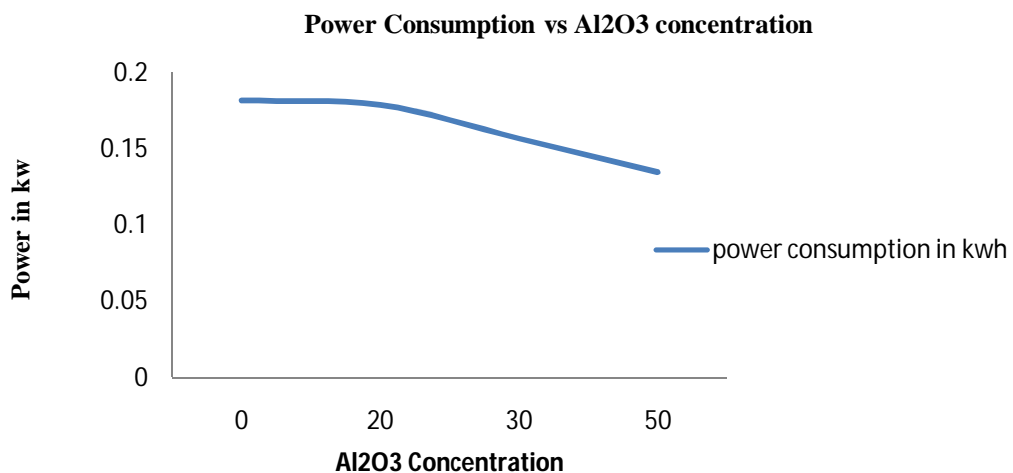
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## Graphs between COP VS Al<sub>2</sub>O<sub>3</sub> concentrations



COP with pure refrigerant R134a is found to be 0.65 and with nano refrigerant R134a + 20 gm of Al<sub>2</sub>O<sub>3</sub> and refrigerant R134a + 30 gm of Al<sub>2</sub>O<sub>3</sub>, R134a + 50 gm of Al<sub>2</sub>O<sub>3</sub> COP is 0.68 and 0.70, 0.73 respectively. So, it has been concluded that with refrigerant R134a + 30 gm of Al<sub>2</sub>O<sub>3</sub> and refrigerant R134a + 50 gm of Al<sub>2</sub>O<sub>3</sub> improvement in performance is 12.3%. Hence there is increase in the COP of the system with addition of nanoparticles in the refrigerant and also with increases in mass fraction of nanoparticles.

## Graphs between Power Consumption VS Al<sub>2</sub>O<sub>3</sub> Concentration



In this study it is found that pure R134a consumes 0.182 kW for temperature reduction from 5°C to -10°C., while nanorefrigerant R134a + 20 gm of Al<sub>2</sub>O<sub>3</sub> and R134a + 30 gm of Al<sub>2</sub>O<sub>3</sub>, R134a + 50 gm of Al<sub>2</sub>O<sub>3</sub> consume 0.179 kW and 0.157 kWh, 0.135 respectively. Figure also shows Reduction in power consumption for nanorefrigerant R134a + 30 gm of Al<sub>2</sub>O<sub>3</sub> and nanorefrigerant R134a + 50 gm of Al<sub>2</sub>O<sub>3</sub> is found to be 13.73% and 25.82% respectively as compared to refrigerant R134a. It has been observed that as concentration of Al<sub>2</sub>O<sub>3</sub> nanoparticles increases, the power input to the refrigeration system decreases.



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## V. CONCLUSION

The present research work entitled “ENHANCING HEAT TRANSFER RATE USING NANO FLUIDS IN REFRIGERTOR” was aimed at, to use nanoparticles in conjunction with R134a refrigerant. It has been decided to use nanoparticles Al<sub>2</sub>O<sub>3</sub> of size 30 nm each. Three concentrations of nanoparticles were taken to compare performance with pure refrigerant R134a.

- (i) The system was charged with nanorefrigerant R134a + Al<sub>2</sub>O<sub>3</sub> with 20 gm, 30 gm and 50 gm mass of nanoparticles.
- (ii) Temperature drop in condenser, temperature gain in evaporator for the system and temperature-time chart were studied for both nanoparticles at both concentrations
- (iii) It was found that addition of aluminum oxide nanoparticles to the refrigerant results in improvement in the thermo physical properties and heat transfer characteristics of the refrigeration system.
- (iv) It was observed that there is more temperature drop across the condenser for the Nanorefrigerant compared to refrigerant R134a. An improvement in COP was also observed during the investigations (12.3%).
- (v) A reduction in the power consumption (13.73% & 25.82%) along with faster cooling is also achieved when nanorefrigerant.

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