EXPERIMENTAL INVESTIGATIONS ON AL_2O_3 NANO REFRIGERANT WITH DIFFUSER AT CONDENSER INLET IN A VCR SYSTEM

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Abstract: In modern days, refrigeration systems are important for industrial and domestic applications. Domestic refrigerators mostly work on vapour compression refrigeration cycle. Performance of any VCR suffers from its poor heat transfer properties of refrigerants to surroundings. Many methods are implemented to transfer heat from condenser. Such as forced convection, fins, number of condenser coils etc. But they increase the cost as well as power consumption by sacrificing the performance of VCR system. Hence the Nano fluids may be a promising solution to the existing problems to increase heat transfer rates in compressor. 0.5% V of Al2O3Nano particles are mixed with POE oil and used as lubricant in compressor (Hermitically shield and Oil cooled) and R600a as refrigerant in 220L capacity refrigerator. Also a diffuser is attached at condenser inlet to convert kinetic energy to pressure energy so as to increase work done without compression. Experiments are conducted to analyse the performance.

Key words- R600a, Al_2O_3 Nano particles mixed with POE oil, Diffuser at condenser inlet.

I INTRODUCTION

In today's world refrigeration systems are important for both domestic and industrial applications. Most of household refrigerators work on vapour compression system. The leakage of refrigerants from refrigerators may cause several problems to environment like ozone depletion, global warming etc. In order to rectify these problems, environmental safety refrigerants like hydrocarbons, their blends etc. are to be used. R600a is one of the environmental safety refrigerants with zero ODP and GWP is less than 3. Performance of VCR system suffers from its poor heat transfer properties of refrigerant to surroundings. Because of the thermal fluid which is used in the systems have less heat transfer coefficients. Many methods are implemented to transfer heat from condenser, such as forced convection, fins, number of condenser coils etc. But there is a need of changing the design of the system as well as they increase the cost and power consumption by sacrificing the performance of VCR system. Hence the Nano fluids may be a promising solution to the existing problems to increase heat transfer rates in compressor and condenser. Nano fluids are directly charged into the system without changing its design. They create turbulence in the pipes due to which heat transfer rate increases. The nano particles (Al, Cu, Al_2O_3 Al_2O_3 etc.) mixed with base fluids (water, refrigerant, engine oil etc.) combined together to form a colloid called nanofluid. The nano particles are in the form of solid, so they have more heat transfer rate than the normal refrigerants. The normal refrigeration cycle has major problems like high compressor work requirement, vibrations in condenser (due to the high velocity of refrigerant after compression). Hence the diffuser may be a promising solution to the existing problem. Diffuser is used to convert the kinetic energy available at compressor outlet to the pressure energy, which leads to reduction in compressor work as well as reducing the vibrations occurred in the condenser.

II LITERATURE REVIEW

Binit Kumar Jha, et.al. [1] Conducted an experimental investigation to compare the COP of VCR system using various refrigerants like R134a and R600a under condition -5^{0}C evaporator temperature. The results showed that the alternative refrigerant investigated in the analysis R600a has higher coefficient of performance. Refrigerant property parameter shows that R600a has minimum leakage, minimum global warming potential and low power consumption when compared with R134a. Adityaswaroop et al. [2] Developed a new cycle with Diffuser at compressor outlet in a VCR system using R134a as a refrigerant to enhance the performance of the cycle. The experiment shows that the kinetic energy obtained at compressor outlet was converted into pressure energy. And the temperature, pressure at the diffuser outlet was increased when compared with that at compressor outlet. Due to this the reduction in compressor work takes place and COP of the system was increased. The experiment shows that the time required for the freezing in evaporator was also quicker than that of normal cycle. Pawel et al. [3] Conducted studies on nanofluids and found that there is the significant increase in the thermal conductivity of nanofluid compared to the base fluid. They also found that addition of nanoparticles results in significant increase in the critical heat flux. Bi et al. [4] Conducted studies on a domestic refrigerator using nanorefrigerants. In their studies R134a was used the refrigerant, and a mixture of mineral oil TiO2 was used as the lubricant. They found that the refrigeration system with the nanorefrigerant worked normally and efficiently and the energy consumption reduces by 21.2%. When compared with R134a/POE oil system. R.K Adyanshee Pattanayak et al. [5] Conducted Performance Analysis of a Domestic Refrigerator using Al_2O_3 Nanoparticles. Results obtained and showed that the coefficient of performance of the refrigerating system was improved by 12.14% for the mass fractions of 0.47% of Al2O3 nanoparticles. There was also reduction of compressor's suction and discharge pressures with addition of nanoparticles. Jwo et al. [6] Conducted studies on a refrigeration system replacing R-134a refrigerant and polyester lubricant with a hydrocarbon refrigerant and mineral lubricant. The mineral lubricant included added Al_2O_3 nanoparticles to improve the lubrication and heat-transfer performance. The power consumption was reduced by about 2.4%, and the coefficient of performance was increased by 4.4% for R-134a and 0.1 wt. % Al2O3 nanoparticles. R.Reji et al. [7] Performed heat transfer enhancement of domestic refrigerator using R600a/mineral oil/nano- Al_2O_3 as working fluid. It was founded that the freezing capacity was higher and the power consumption reduces by 11.5 % when POE oil was replaced by a mixture of mineral oil and Aluminium oxide nanoparticles. Thus using Aluminium oxide nano-particles in refrigeration system was feasible and the coefficient of performance of the refrigeration system also increases by 19.6 % when the conventional POE oil is replaced with nano-refrigerant.

In the present study the refrigerant selected is R600a and the nanoparticle is aluminium oxide. Isobutene (R600a) is more widely adopted in domestic refrigerator because of its better environmental and energy performances. A new refrigerator test system was built up according to the requirement of this study. 0.5% V and 50nm-200nm size of Al_2O_3Nano particles mixed with POE oil used as lubricant and R600a is used as refrigerant in 220L capacity refrigerator. Also a diffuser is attached at condenser inlet to convert kinetic energy available at condenser inlet to pressure energy so as to increase work done without actual compression. The freeze capacity test was conducted to compare the performance of the refrigerator with and without nano refrigerant so as to provide the basic data for the application of the nanoparticles in the refrigeration system.

III EXPERIMENTAL SETUP & METHODOLOGY

The layout of the tested refrigeration cycle as shown in figure 1. The main components are R600a compressor, proposed diffuser, condenser, capillary tube expansion valve. The diffuser is placed after compressor as shown in figure 2. The diffuser has actually made with copper and having dimensions as shown in figure 5. The main objective of diffuser is to convert kinetic energy into pressure energy. In the proposed layout of the tested refrigeration system, the diffuser is placed in between compressor and condenser in order to reduce compressor work which enhances the vapour compression system efficiency. Further advantage of the diffuser is that it reduces the tube vibration associated with the operation of the condenser and increases the heat transfer rate through the condenser.

Fig 1: experimental refrigerator

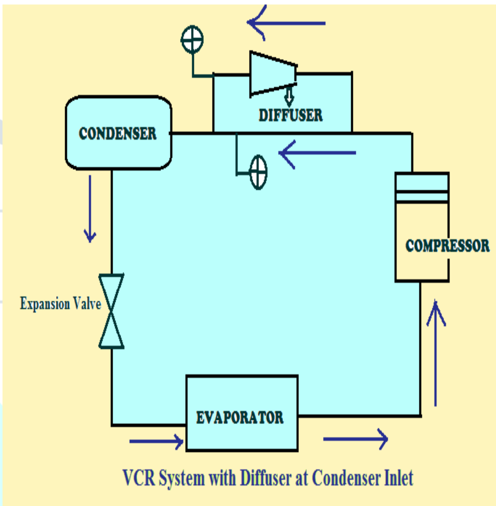

Fig 2: Line Diagram for experimental refrigerator

Fig 3: Diffuser

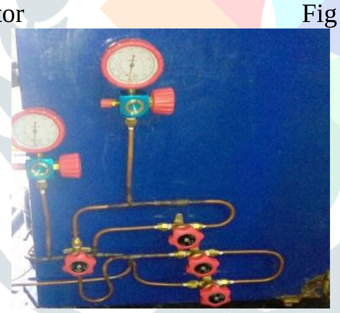

Fig4: Diffuser connection in the proposed model

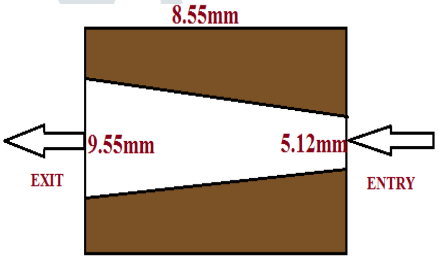

Fig 5: Line Diagram of Diffuser

A) Nano fluid preparation:

A two-step method of nano-fluid preparation is used in this study. The first step involves in the drying, storage, and transportation of nanoparticles into a conical flask. Al_2O_3 with an average size of 50nm-200nmand 0.5% wt. concentration by volume is used. In the second step the nanoparticles Al_2O_3 are directly mixed in the base fluid POE oil and thoroughly stirred with a hot plate stirrer to become POE- Al_2O_3 nano-lubricant, followed by ultrasonic homogenization for about 3-4 hours. Frequent use of ultra-sonication or stirring is required to reduce particle agglomeration. Sedimentation was conducted after the homogenization process in order to check the stability of the POE-Al_2O_3nano-lubricant. The preparation process is as shown in figure 6.

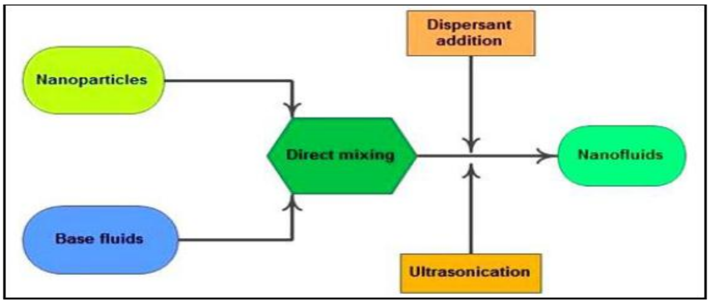

Fig 6: Two step preparation process of nanofluids

B) Experimental Procedure:

After the evacuation, various leakage tests like nitrogen and bubble tests and water submersion methods are done to confirm no leakage in the system. Then 400ml of nano-fluid is inserted to the compressor through the service port and allowed to stabilize for 15-20 minutes. After that 60gm of R600a is charged into the system. The refrigerant flows through the diffuser by opening the valves as shown in figure 4.The temperature and pressure measured at the compressor inlet, diffuser inlet, condenser inlet, evaporative inlet, expansion inlet and outlet with the help of thermocouples and pressure gauges. The ranges of pressure gauges for evaporator inlet/outlet and compressor inlet are 0 to 1.75MPa and for condenser inlet/outlet and compressor outlet is 0 to 3.5MPa.

IV RESULTS AND DISCUSSION

A) Time Vs. Evaporator Temperature:

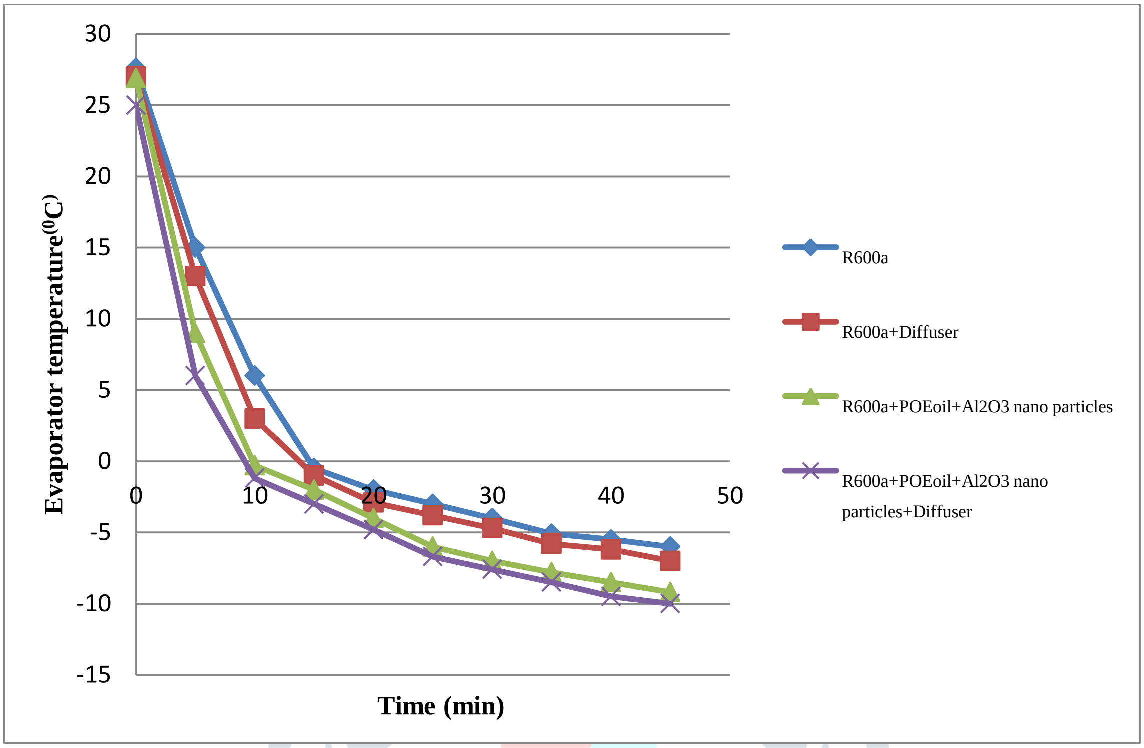

Fig 7: Time Vs. Evaporator Temperature

The figure 7 shows that the variation of time with respect to the evaporator temperature. As the temperature of evaporator decreases the time required is increases for all the cases of experiment. The figure 7 shows that the change in evaporator temperature has decreased after 30minutes, because of the evaporator temperature is stabilized around -5^{0}C. The time required for getting -7^{o}C is less in Al_2O_3+POE oil when compared with normal R600a cycle. The time taken for getting -6^{o}C in normal cycle of R600a is 45’20”.The time taken for getting the same temperature with diffuser at condenser inlet to the normal cycle is 42’43”. The time taken for getting the same evaporator temperature with Al_2O_3+POE oil to the normal cycle is 29’16”. And the time taken for getting the same temperature (-7^{o}C) with Al_2O_3+POE oil along with diffuser at condenser inlet to the normal cycle of R600a is 27’13’’. Thus the time taken for getting the same evaporator temperature (-7^{o}C) is less in the case of Al_2O_3+POE oil along with diffuser at condenser inlet cycle.

B) Comparison of Compressor Work Required for Ton of Refrigeration:

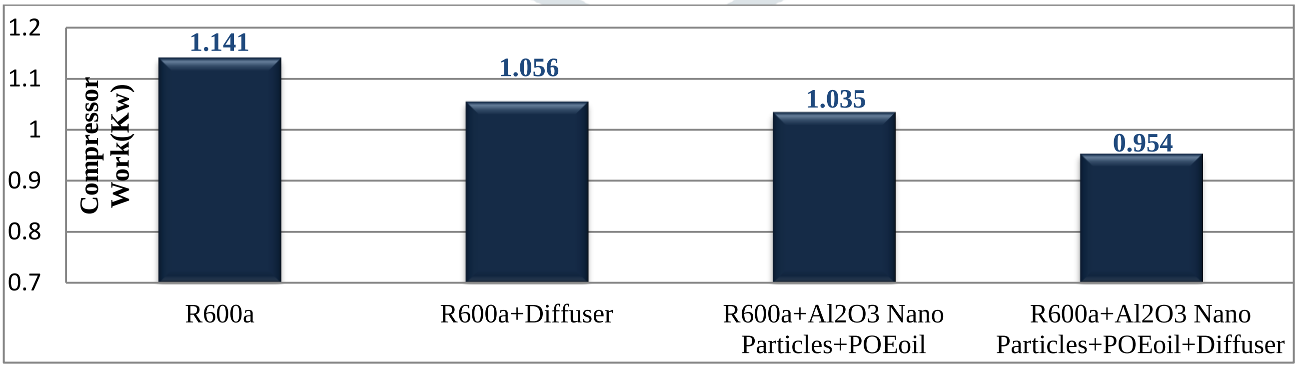

Fig 8: Comparison of Compressor Work Required for Ton of Refrigeration

The figure 8 shows that compressor work required for ton of refrigeration is less in the case of R600a with Al_2O_3+POE oil along with diffuser at condenser inlet when compared with R600a normal cycle. The Al_2O_3+POE oil increases the heat transfer rate in the compressor. Therefore the specific volume of compressed refrigerant decreases which leads to reduction in compressor work. And the diffuser facilitates static pressure recovery of the refrigerant entering the condenser, thereby increasing the pressure of the refrigerant leaving the diffuser compared to the pressure of refrigerant entering the diffuser, which leads to reduction in compressor work. The compressor work saved due to diffuser at condenser inlet to the normal cycle is7.45%. The compressor work saved due to Al_2O_3+POE oil cycle when compared with normal cycle is 9.30%. The compressor work saved due to Al2O3+POE oil along with diffuser at condenser inlet when compared to the normal cycle is 16.34%.

C) Comparison of Refrigeration Effect throughout the Experiment:

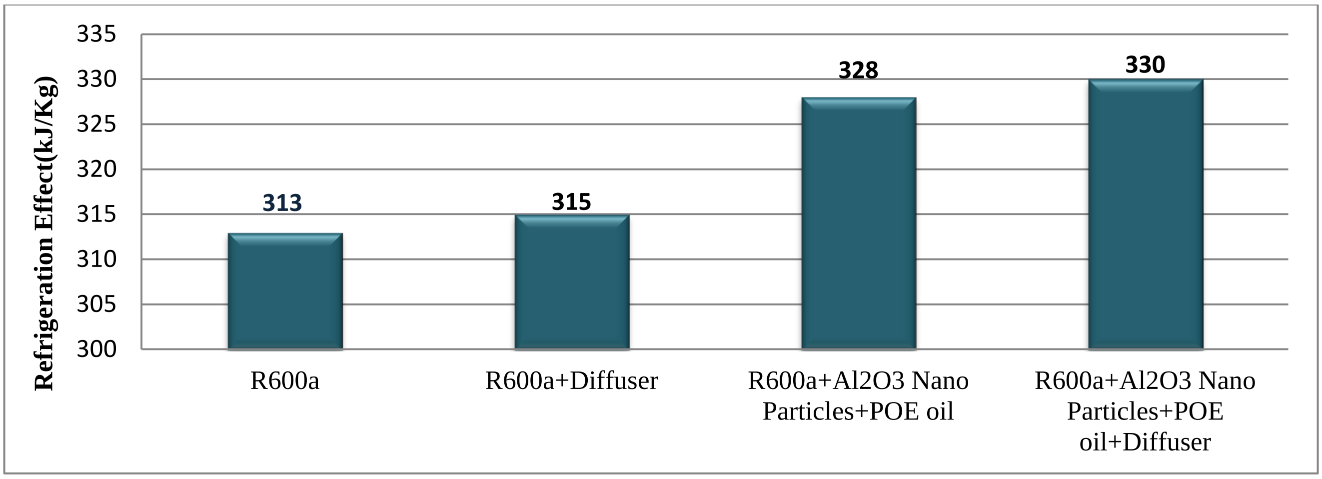

Fig 9: Comparison of Refrigeration Effect throughout the Experiment

The figure 9 shows that the refrigeration effect for R-600a using Al_2O_3+POE oil along with diffuser at condenser inlet is more when compared with normal cycle. The Al_2O_3+POE oil increases the heat transfer rate at all the components. The diffuser also increases the heat transfer rate through the condenser due to the temperature difference is more at condenser. Due to this the refrigerant temperature at condenser outlet is just before the saturated liquid line as shown. That means sub cooling is obtained at the exit of the condenser. Therefore the refrigeration effect increases in the case of R600a using Al_2O_3+POE oil along with diffuser at condenser inlet when compared with normal cycle.

D) Comparison of COP throughout the Experiment:

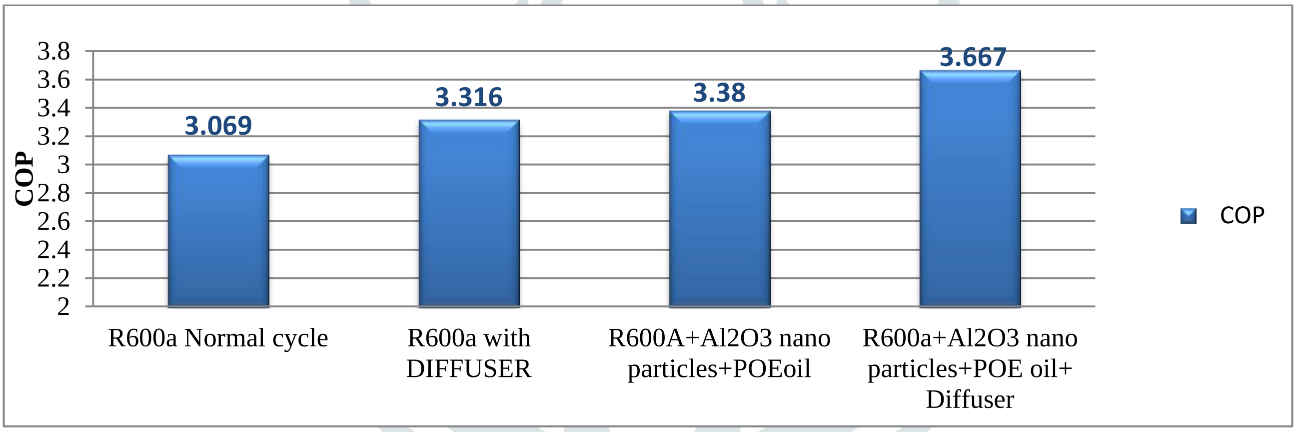

Fig 10: Comparison of Coefficient of Performance

The figure 10 shows that the coefficient of performance for R-600a using Al_2O_3+POE oil along with diffuser at condenser inlet is higher than the R600a with normal cycle. Due to the reduction in compressor work, increase in refrigeration effect the coefficient of performance is more with Al_2O_3+POE oil along with diffuser at condenser inlet. The percentage increase of COP with diffuser at condenser inlet to the normal cycle is 8.04%. The percentage increase of COP for Al_2O_3+POE oil cycle when compared with normal cycle is 10.13%. The percentage increase of COP for Al_2O_3+POE oil along with diffuser at condenser inlet when compared to the normal cycle is 19.48%. The above all effects are due to the reduction in compressor work by diffuser, increase in refrigeration effect by Al_2O_3+POE oil.

E) Performance comparison of R600a Normal cycle to R600a Using Al_2O_3+POE oil along with diffuser at condenser inlet:

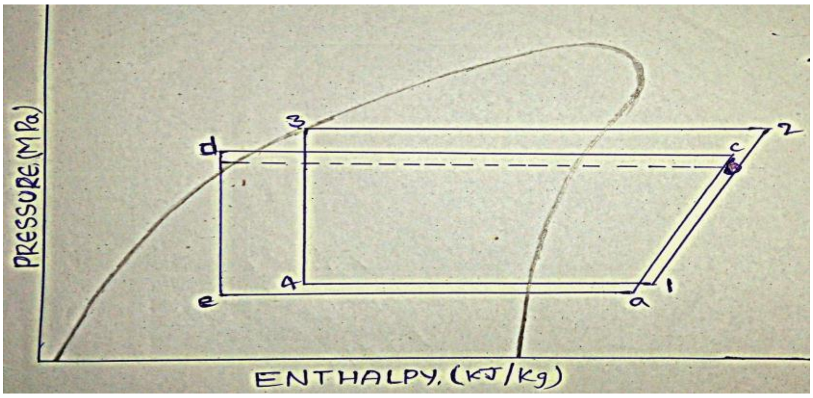

Fig 11: Performance comparison of R600a Normal cycle to R600a Using Al_2O_3+POE oil along with diffuser

1-2-3-4 R600a with Normal Cycle
a-b-c-d-e R600a using Al_2O_3+POE oil along with diffuser at condenser inlet.

Due the better heat transfer rate property of the Al_2O_3+POE oil the temperature after compression ($T_b{}^0C$) is less when compared with normal cycle temperature ($T_2{}^0C$). Therefore the specific volume of compressed refrigerant decreases which leads to reduction in compressor work when compared with the normal cycle. The compressor work in the system is (h_b-h_a) kJ/Kg. when diffuser valves are opened in the same system the diffuser work obtained is (h_c-h_b) kJ/Kg. Then the reduction of compressor work due to diffuser is [(h_b-h_a) - (h_c-h_b)] kJ/Kg. The diffuser increases the heat transfer rate through the condenser as well as the nano fluid also increases heat transfer rate through the condenser. Because of these reasons the temperature at condenser outlet also decreases and sub cooling is obtained at condenser outlet, which leads to increase of refrigeration effect. Therefore the COP of the Al_2O_3+POE oil along with diffuser at condenser outlet cycle is increases when compared with normal cycle of the R600a refrigeration.

The coefficient of performance of R600a & Al_2O_3+POE oil along with diffuser cycle = **(h_a-h_e) / [(h_b-h_a) - (h_c-h_b)]**

V CONCLUSIONS

An experimental analysis is performed on Vapour Compression Refrigeration System with R600a used as refrigerant and the system is run for four cases. Those are normal cycle, diffuser at condenser inlet cycle, Al_2O_3nano particles+POE oil cycle and Al_2O_3nano particles+POE oil along with diffuser at condenser inlet cycle. In these four cases the performance parameters like Refrigeration effect, Compressor work and COP are investigated and evaluated. In the case of R600a with Al_2O_3nano particles+POE oil along with diffuser at condenser inlet cycle, the refrigeration effect is increased by 5.04%, the compressor work is decreased by 16.34% and the overall coefficient of performance is increased by 19.48% when compared with normal cycle. Hence it can be concluded that the cycle with Al_2O_3nano particles+POE oil along with diffuser at condenser inlet has better performance and take less time for the same freezing capacity when compared with normal cycle.

APPENDEX

a) Properties of POE oil:

Viscosity	32 m^2/sec
Flash point	258^0C
Pour point	-46^0C
Miscibility temperature	-42.2^0C
Density	0.977 Kg/L
Acid value	<0.05

b) Properties of Al_2O_3 Nano Particles:

Property	**Description**
Melting Point	2072^0C
Boiling Point	2977^0C
Colour	Ivory/White
Density	$0.26*10^{-3}$ Kg/m^3
Specific Heat	880 J/KgK
Thermal Conductivity	30 W/Mk
Molecular Mass	0.10196 Kg/mol
Specific Surface Area	500 – 50000 m^2/Kg
Appearance	White Powder
pH	7-9

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