Enhancing the Thermal Performance of Libr-H_2o Vapor Absorption System by the Addition of Cuo Nanoparticles

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Abstract:

In this study, the performance analysis of vapor absorption refrigeration system (VARS) using CuO nanoparticles in LIBr-H_2O working fluid is studied. The performance of VARS is analyzed by considering key system parameters such as operating temperature of absorber, condenser, generator and evaporator. Herein new stable working fluid for VARS is prepared by the addition of CuO nanoparticles. In this study nanoparticles are dispersed by ultrasonically in LiBr-H_2O working fluid using a tip sonicator with intermittent sonication time. For experimentation a physical model of 1 TR capacity VARS has been designed and developed. The results indicate that there is enhancement of 17% in coefficient of performance by the addition of CuO nanoparticles in LiBr-H_2O working fluid. For all the operating temperature the heat exchanged in evaporator, absorber, condenser and generator is higher with nanoparticle base working fluid than without nanoparticle base working fluid. Thus this new solution has a potential for the improvement of performance of vapor absorption technology and will reduce global warming and peak electricity demand.

Keywords: Vapor absorption refrigeration system, CuO nanofluids, LiBr-H_2O working fluid, coefficient of performance, generator temperature.

1. INTRODUCTION

In the present universe the production of cold plays an important role. Conventional vapor compression refrigeration system have some attractive features like less volume per unit cooling capacity, higher coefficient of performance per unit cost. Conventional refrigeration and air conditioning system consumes high quality energy in the form of electricity. As per the study of the International institute of refrigeration (Paris) the refrigeration and air conditioning unit consumes near about 15% of the world's production of total electricity. Commercial and residential building uses more than 50% of supplied energy for the air conditioning purpose. Electric energy consumption for the cold production varies from country to country. In the middle east countries more than 50% of energy is required for the air-conditioning due to the extreme hot and humid climate.

Conventional system uses CFC's and HCFC's gases which have higher potential for global warming and ozen layer depletion. International agreements are signed for the reduction of greenhouse gases. Therefore researchers are interested for the development of technologies that can minimize peak electrical demand, cost and energy consumption. These effects can be reduced by choosing nanofluid base vapor absorption refrigeration system (VARS) as an alternate technology to the vapor compression refrigeration system (VCRS). Vapor absorption refrigeration system can be operated on low grade energy source like solar energy, waste energy from industrial processes.

VARS has less running and maintenance cost as compared to the VCRS. Till date VARS is not commercially accepted by the industries due to its lower performance, high cost and large volume. Addition of the nanoparticles to the working fluid is the one of the recent development for the performance improvement of the VARS. Nanoparticles Brownian motion, high surface area to volume ratio has influenced the researcher to use nanoparticles for the enhancement of the heat transfer rate. Many researchers have reported the positive effect of nanoparticles on the performance of the heat transfer fluids. Choi et al [1] prepared nanofluids and reported that nanofluids possess extremely large surface area. The larger surface area of nanoparticles improves the heat transfer capabilities and stability of the suspension. Yang et al [2] studied nanofluids and found that the increase in the heat transfer rate of nanofluid is higher than the increase in thermal conductivity. Hussain et al [3] studied forced convection heat transfer of SiO_2 nanoparticle dispersed in water base fluid. They found that Nusselt number increases with increase in flow rate and nanoparticle volume concentration. Nanofluid with low concentration can enhance the heat transfer rate up to 50%. M. Hasanuzzamana et. al. has calculated convective heat transfer coefficient of water, Al-water, Cu-water Al_2O_3-water and $Ti0_2$-water for 2% nanoparticle concentration in counter flow heat exchanger. The author found that convective heat transfer coefficient of Cu-water, Al-water, Al_2O_3-water and $Ti0_2$-water nanofluids are 81 %, 63%, 66% and 64% higher compared to pure water respectively [4-6]. Nanofluids can be considered as a potential candidate for many applications. Application of nanofluids in heat exchanging devices makes them more energy efficient and compact [7-10]. The absorber and generator are the two main components of VARS. These two components are responsible for the low performance of the VARS as compared to the VCRS. Addition of the nanoparticles to the base fluid will enhance the rate of heat transfer in absorber and generator. Very few researchers have studied effect of addition of nanoparticles on the performance of VARS[11]. V. marriappam et al. have done the thermodynamic analysis of R134A-DMAC VARS. They added Al_2O_3 nanoparticles in R134A refrigerant. They found that the COP of system is increased by15%. Their results also show that the mass flow rate of strong solution decreases by the increment of Al_2O_3 nanoparticle concentration[12-13]. Gulati et al have studied the effect of seeding of Al_2O_3 nanoparticles in NH_3-H_2O refrigeration absorption system. Their experimental result indicates that addition of nanoparticles enhances the performance of system due to the scattering effect of nanoparticles[14]. Talpada et al studied thermodynamic behavior of VARS by the addition of Al_2O_3 nanoparticles in H_2O-LiBr fluid. They reported that by addition of nanoparticles COP of system increases up to 35% for set generator temperature range. The heat transfer in evaporator with nanoparticles is higher than system without nanoparticles for all operating temperature[15].

As per the research review very less efforts has been done on nanoparticle base vapor absorption system. Thus herein we have studied experimental analysis of CuO nanoparticle base vapor absorption system. CuO nanoparticles are added to H_2O-LiBr working fluid for the improvement of the system performance. Performance of new system have been measured for the various system parameters and compared to the conventional vapor absorption refrigeration system for all the operating temperature range.

2. EXPERIMENTAL SET UP

Instrumented vapor absorption refrigeration system is designed and developed for the experimental investigation. The schematic diagram of experimental setup is shown in figure 1. The test setup is designed for 1TR capacity and consist of absorber, generator, condenser, evaporator, expansion valve, heat exchangers and solution pumps. The shell and tube type heat exchanger configuration is used while manufacturing condenser, generator, absorber and evaporator. Hot water tank is attached with 5 KW electric heater and supplies hot water to the generator. Overhead tank is used for supplying the cooling water to the absorber and condenser. A diaphragm pump is used for the circulation of the strong solution. The pressure, temperature and flow rate is measured at different points as indicated in figure 1. For the measurement of the temperature PT-200 type calibrated thermocouple (Range 0^0C to 200^0C) is used. Rotameter of range (0-100 LPH) are used for the flow measurement of strong and weak solution mass flow rate and condensate mass flow rate. Vacuum pressure gauge (0-760 mm of Hg) is attached to the evaporator and generator for the measurement of vacuum pressure.

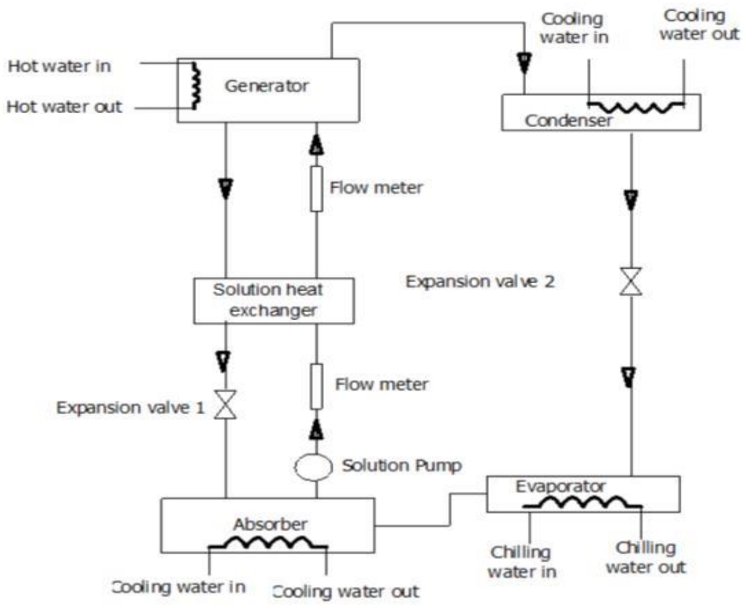


Figure 1

A leakage and vacuum test has been performed for the components of the system. Vacuum pump is connected to the condenser and evaporator and desired vacuum pressure is maintained. The charging of CuO based H_2O-LiBr solution is carried out in a evacuated system. The hot water tab and cooling water tabs are operated for the supply of hot water to generator and cooling water to condenser and absorber. The solution pump circulate the strong solution from absorber to generator. The cooling effect is produced in the evaporator. The water to be chilled is supplied to the evaporator from the chilled water pump. The flow meters are used to measure the desired mass flow rate of water.

3. OBSERVATIONS AND CALCULATIONS

The mass flow rate of various fluids for different generator temperature whereas below-

a- Generator hot water flow rate = 0.50 kg/s
b- Absorber cooling water flow rate = 0.17 kg/s
c- Condenser cooling water flow rate = 0.22 kg/s
d- Chilled water flow rate = 0.12 kg/s
e- Strong solution flow rate = 0.00692 kg/s
f- Weak solution flow rate = 0.00575 kg/s

Nanofluid mixture is prepared by adding CuO nanoparticles of average diameter 40-50nm in a deionized water. Nanoparticles are dispersed by ultrasonically in liquid using a tip sonicator with intermittent sonication time. Ultrasonic frequency (>20 kHz) is used for sonication. Then this stable nanofluid mixture is added in H_2O-LiBr binary mixture.

The heat transfer of different element is calculated by the measurement of flow rate of fluids and inlet and exit temperatures of fluids.

Heat transfer = Q = mh*Cpw*($T_{out} – T_{in}$)

Where mh = mass flow rate

Cpw = Specific heat of water

T_{out} ,T_{in} = Outlet and inlet temperature of water

Coefficient of performance = $COP = \frac{\text{Heat transfer in evaporator}}{\text{Heat transfer in generator}}$

4. RESULTS AND DISCUSSION

The performance parameter curves of nanoparticle based vapor absorption refrigeration system (VARS) are plotted for different operating conditions.

4.1 Effect of Generator temperature and absorber temperature on coefficient of performance (COP)

The variation of COP with different generator and absorber temperature is presented in figure (2-4). Figure 2 shows the comparison of COP at constant condenser temperature (Tc=20^0c), evaporator temperature (Te=10^0c) for different generator and absorber temperature. The graph shows that COP of system decreases with increase in generator inlet temperature and absorber temperature. Coefficient of performance is highest at 20^0c absorber temperature and 60^0c generator inlet temperature. For all the values of the absorber and generator temperature performance of nanoparticle VARS system is better than that of without nanoparticle VARS system. From the graph it is also clear that the decrement of the COP for normal system is more than that of nanoparticle base system for all temperature range. Nanoparticle based system is more stable and shows small variation in COP for the entire generator operating temperature. It is also clear from the graph that as evaporator temperature is decreased from 10^0C to 4^0C the COP value also decreases from 0.797 to 0.656 for 65^0c generator temperature. For 4^0c evaporator temperature the variation of COP with generator temperature is more in comparison with evaporator temperature 7^0c and 10^0c.

4.2 Effect of Generator temperature and condenser temperature on coefficient of performance (COP)

The effect of generator and absorber temperature on COP is presented in figure (5-7). Figure 5 shows the comparison of COP at constant absorber temperature ($Ta=20^0$c), evaporator temperature ($Te=10^0$c) for different generator and condenser temperature. The graph indicates that COP of system decreases with increase in generator inlet temperature and absorber temperature. The result indicates that COP is highest at 20^0c condenser temperature and 60^0c generator temperature. It is noticed that for all the values of the condenser and generator temperature performance of nanoparticle VARS system is better than that of without nanoparticle VARS system. From the graph it is also clear that the decrement of the COP for normal system is more than that of nanoparticle base system for all temperature range. Nanoparticle based system is more stable and shows small variation in COP for the entire generator operating temperature.

4.3 Effect of Generator temperature and evaporator temperature on coefficient of performance (COP)

The influence of generator and evaporator temperature on COP is shown in figure (8-10). Figure 8 shows the comparison of COP at constant absorber temperature ($Ta=20^0$c), condenser temperature ($Tc=20^0$c) for different generator and condenser temperatures. The graph indicates that COP of system decreases with increase in generator inlet temperature and decrease in evaporator temperature. The result indicates that COP is highest at 10^0c evaporator temperature and 60^0c generator temperature. It is noticed that for all the values of the condenser and generator temperature performance of nanoparticle VARS system is better than that of without nanoparticle VARS system. From the graph it is also clear that the decrement of the COP for normal system is more

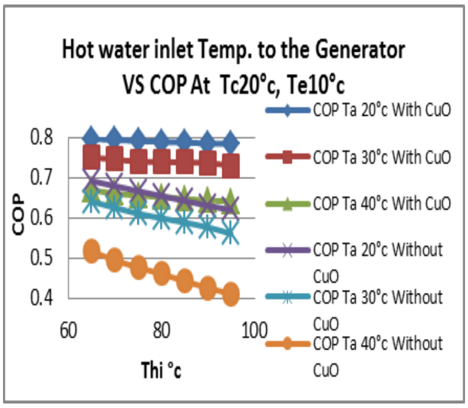
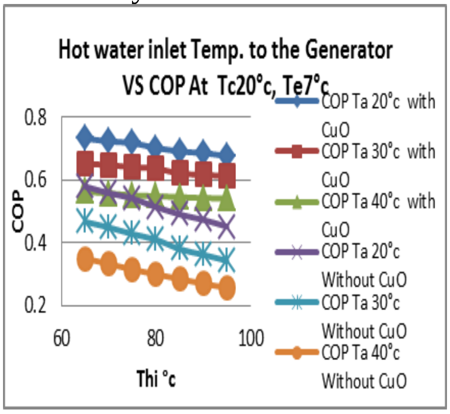


Figure 2



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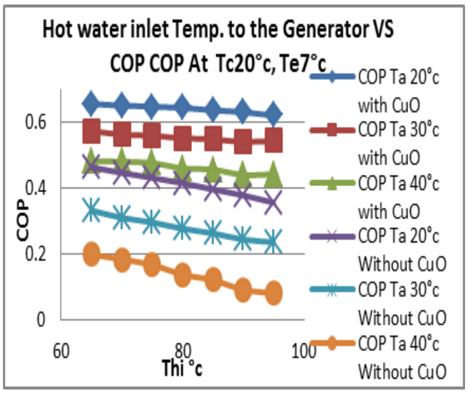

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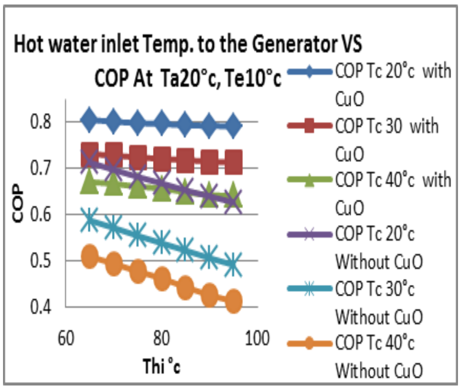

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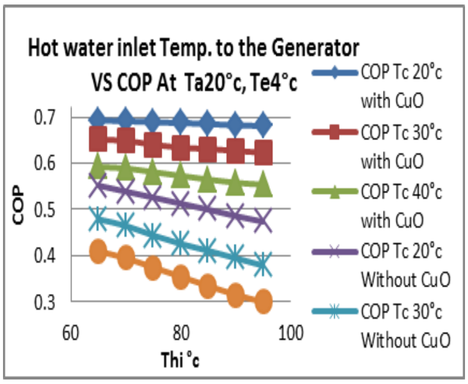

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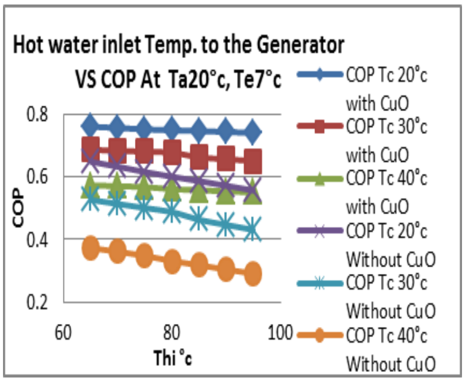

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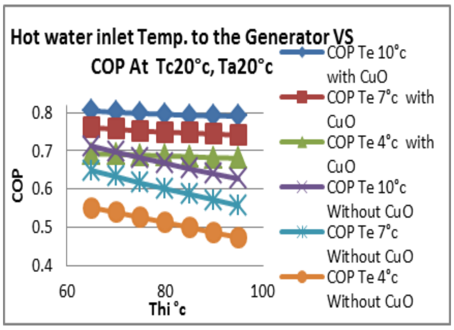
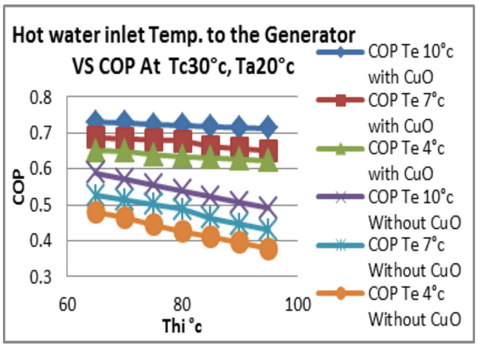


Figure 8



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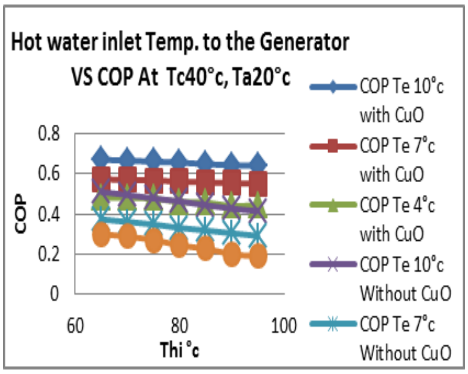


Figure 10

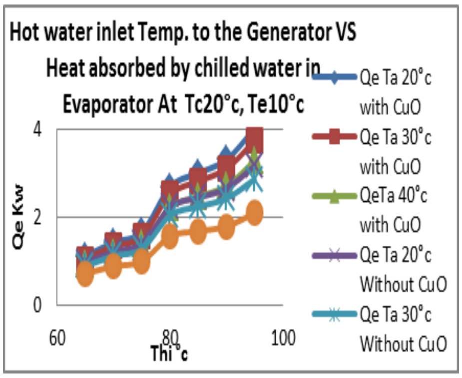
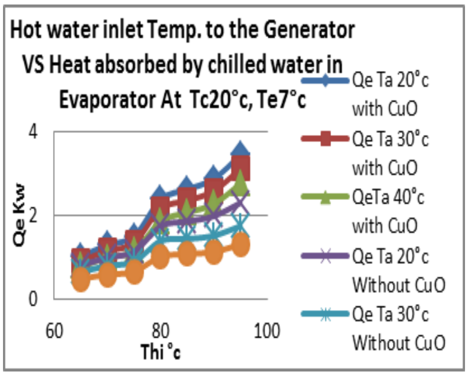


Figure 11



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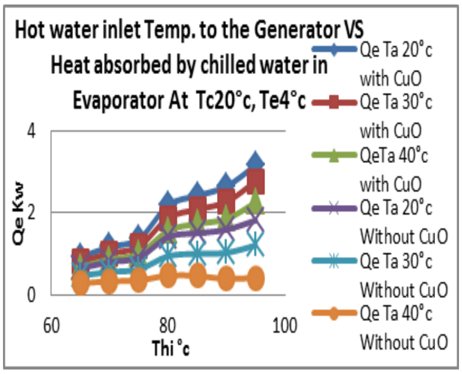

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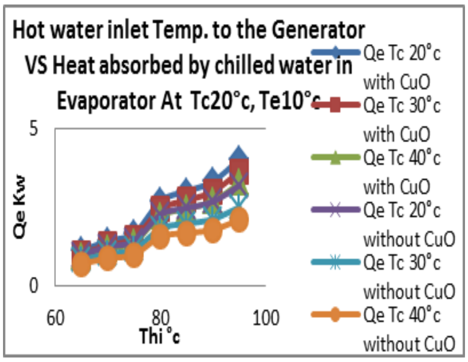

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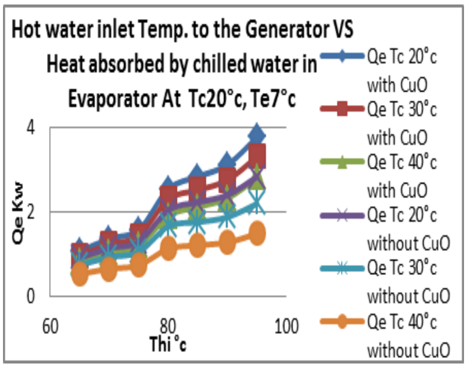

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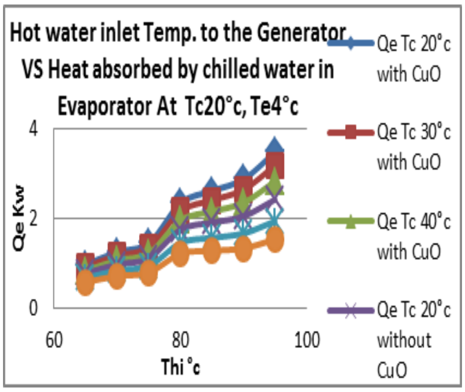

Figure 16

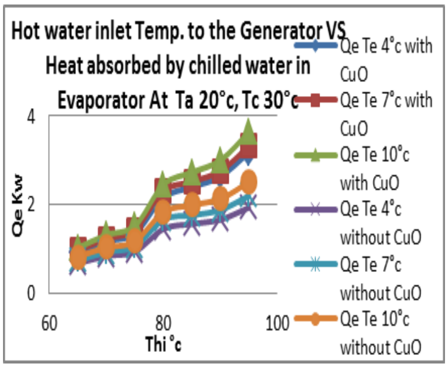

Figure 17

than that of nanoparticle base system for all temperature range. It is also clear from the graph that as absorber temperature is increased from 20^0c to 40^0c the COP value also decreases from 0.815 to 0.671 for 65^0c generator temperature. For 40^0c condenser temperature the variation of COP with generator temperature is more in comparison with condenser temperature 20^0c and 30^0c.

4.4 Effect of Generator temperature, absorber temperature, condenser temperature and evaporator temperature on Heat absorbed in Evaporator (Qe)

The variation of generator, absorber, condenser and evaporator temperature on heat absorbed in evaporator shown in figure (11-15). Figure 11 shows the comparison of Heat absorbed in Evaporator at constant evaporator temperature (Te=10^0c), condenser temperature (Tc=20^0c) for different generator and evaporator temperatures. The graph indicates that heat absorbed in evaporator increases with increase in generator inlet temperature and decreases with increase in absorber temperature. The result indicates that heat absorbed in evaporator is highest at 10^0C evaporator temperature, 20^0C absorber temperature and 60^0C generator temperature. It is noticed that for all the values of the condenser, evaporator, absorber and generator temperature performance of nanoparticle VARS system is better than that of without nanoparticle VARS system. From the graph it is also clear that the decrement of the heat absorbed in evaporator for normal system is more than that of nanoparticle base system for all temperature range. Nanoparticle based system is more consistent and shows small variation in heat absorbed in evaporator for the entire generator operating temperature.

5. CONCLUSION

In this study the experimental analysis of Lithium bromide-water vapor absorption system with CuO nanoparticles and without CuO nanoparticles is carried out. For experimentation and investigation 1 TR capacity VARS has been designed and developed. From the experimental analysis following concluding remarks are obtained.

1 The coefficient of performance of nanoparticle base VARS is higher than without nanoparticle base VARS system for the entire generator operating temperature. By the addition of CuO nanoparticles the coefficient of performance of the system is increased up to 17 %.

2 The coefficient of performance of nanoparticle base VARS is higher than without nanoparticle base VARS system for the entire generator operating temperature. By the addition of CuO nanoparticles the coefficient of performance of the system is increased up to 17 %.

3 The rate of heat transfer from the generator is increased up to 23% with the nanoparticle base system in comparison with non-nanoparticle base system.

4 The rate of heat exchanged in the evaporator for nanoparticle base system is more than the system without nanoparticles. The rate of heat transfer increment is up to 29% for the nanoparticle base system.

5 Heat absorbed in evaporator is highest at 10^0C evaporator temperature, 20^0C absorber temperature and 60^0C generator temperature The coefficient of performance of the system decreases with increase in the generator temperature (beyond 70^0C) and absorber temperature. The decrement of coefficient of performance for non-nanoparticle base system is more than that of nanoparticle base system.

6 Nanoparticle based system is more stable and shows small variation in COP for the entire generator operating temperature For effective results the vacuum pressure inside the evaporator must be maintained

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