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Enhancing the Efficiency of Industrial Air-conditioning System using Nano Particle

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Abstract: In our aim is enhancing the efficiency of industrial air conditioning system with nano particle to increase the coefficient of performance. Due to the increase in machine technology and there is a lot of new innovation of air conditioner and its components, to make sure the proper running of machinery system, air conditioner and its cooling system. In this work planned to build a chilled water air conditioning system (HVAC) to reduce the improper working of the air conditioner which required cooling. This chiller plant is play a major role in these works and its benefits. This chiller plant system can used in the required places and reduce the power consumption. To avoid the environmental issue the water is flowing through the inside the air conditioner system to make sure the cooling water temperature. Introducing a ZnO as the nano particle, this nano particle have a good thermal conductivity, the heat transfer of the chiller plant system increases when the use of nano particle. The system has been running for certain period and it can be in off state for a certain period of time after it reaches the temperature range, to reduce the power consumption and the maintenance of the chiller plant. Experimental result indicates the comparative performance of the chilled water air conditioning system with and without use of nano particle which increase the 22% C.O.P of the system.
Keywords: Chilled water air conditioning system, Nanoparticle, Zinc oxide(ZnO), Refrigerant(R22), Chiller, Nano fluid, Coefficient Of Performance.

I. INTRODUCTION

As a result of the multiple applications of chilled water air conditioning systems especially in large zones designs, needs to more savings in energy resources which need unconventional creatively ideas to enhance the system performance with a reduction in consuming power. Poor thermal characteristics of traditional fluids such as water, oil, glycerine, ethylene glycol and other liquids give a challenge to there searchers to enhance its thermal properties to rapid the heat transfer rate per unit time.

Nanotechnology is a revolution in the field of technology and was exploited for several applications in industry, medicine, and agriculture. Nanoparticles are produced by reduction its size to less than 100 nm which has a unique favourite property to be applied. Nano-metals are added to the conventional fluid to form what is called nanofluid.

Nanofluids are embedded suspensions enclosing nanoparticles of less than 100 nm in traditional base fluids. Nanofluids offer higher thermofluid properties compared to traditional base fluids. Nanofluids gain higher thermal conductivity which enhances the performance of heat transfer equipment. The improvement of heat transfer by nanofluids could be compacting the design of heat exchangers and hence reduction in cost. Because of the air conditioners consume about 40–50% of the total electric power of the air-conditioned zones, it has become a fertile field in front of researchers to seek alternatives to reduce the consumed power rates. So, several studies have been exploited the nanofluid significant thermal effect due to their energy efficiency in the engineering applications.

Nanoparticles can be utilized in an expansive scope of improving the HVAC systems performance because of their improved both heat transfer rate and energy efficiency. The present investigation is concerned to study the performance characteristics of the vapour compression refrigeration cycle associated with a chilled water air conditioning system using nanofluid. The influence of nanofluid concentration ratio, nanoparticle type and nanofluid volumetric flow rate on the performance characteristics are discussed with comparing to pure water as the working fluid of a chilled water air conditioning system.

The hybridization is improving the thermofluid properties that strongly depended on the mixture ratios and consequently changes in other physical properties. This emphasizes the importance of studying the performance characteristics of the vapor compression refrigeration cycle integrated with a chilled water system in the case of pure water, nanofluid. From this point, the current work examines the effect of the concentration ratio of nanomaterials on the performance of an air conditioning system associated with a chilled water system.

II. CHILLED WATER AIR CONDITIONING

Chilled water air conditioning systems are commonly used in applications that need large cooling capacity such as hypermarket, industrial process and commercial air conditioning such as offices and factories. More and more homes are using this system to air conditioned their entire house because of its cost-effectiveness and no hazard of having refrigerant piped all over the house. As its name suggest, this system makes use of water as its secondary refrigerant. In a chilled-water system, the entire air conditioner is installed on the roof or behind the building. It cools water to between 40 and 45 degrees Fahrenheit (4.4 and 7.2 degrees Celsius).
The chilled water is then piped throughout the building and connected to air handlers. This can be a versatile system where the water pipes work like the evaporator coils in a standard air conditioner. If it's well-insulated, there's no practical distance limitation to the length of a chilled-water pipe. Chilled water systems in residential HVAC systems are extremely rare. A typical chiller uses the process of refrigeration to chill water in a chiller barrel. This water is pumped through chilled water piping throughout the building where it will pass through a coil. Air is passed over this coil and the heat exchange process takes place. The heat in the air is absorbed into the coils and then into the water. The water is pumped back to the chiller to have the heat removed. It then makes the trip back through the building and the coils all over again. It is used as a refrigerant to remove heat from the building. The chilled water circulates through a chilled water loop and through coils located in air handlers. Chilled water systems include other HVAC equipment designed to exchange heat such as computer room air conditioners. The chilled water absorbs the heat from the building. It then returns to the chiller where the chiller removes the heat from the water using the refrigeration process. Some chilled water loop arrangements are very complex while others are simple. Control of the chilled water from pressure to velocity, to volume, is up to the control system controlling the pumps and valve actuators in the system. Chilled water systems are used in medium and large-sized buildings. Chiller plants act as a centralized cooling system that provides cooling for an entire building or even multiple buildings. This is because it is often more practical to centralize air conditioning equipment in one location rather than install many pieces of equipment in many different place.

A. Components Of Chilled Water Air Conditioning System

1) *Chiller:* The chiller is the section of the system where an exchange of heat occurred between the water that goes to the building and the evaporator. The water leaves the chilled water evaporator at 45°F or 7°C. This chilled-water is then circulated through the entire building by the use of a pump. In compression chiller, compressors are used to compress the refrigerant vapour in the condenser where it becomes liquid. In water-cooled condenser, the heat of the refrigerant liquid is rejected to the water using the shell and tube, shell and coil or double tube heat exchanger.
2) *Compressor:* The compressor is the the prime mover, it creates a pressure difference to move the refrigerant around the system. There are various designs of refrigerant compressors, the most common being the centrifugal, screw, scroll and reciprocating type compressors. Each type has it's own pro's and con's. It is always located between the evaporator and the condenser. It's usually partly insulated and will have an electrical motor attached as the driving force, this will be either mounted internally or externally.
3) *Condenser:* The condenser is located after the compressor and before the expansion valve. The purpose of the condenser is to remove heat from the refrigerant which was picked up in the evaporator. There are two main types of condensers, Air cooled and Water cooled.
4) *Expansion Valve:* The expansion valve is located between the condenser and the evaporator. It's purpose is to expand the refrigerant reducing its pressure and increase it's volume which will allow it to pick up the unwanted heat in the evaporator.
5) *Evaporator:* The evaporator is located between the expansion valve and the compressor, its purpose is to collect the unwanted heat from the building and move this into the refrigerant so that it can be sent to the cooling tower and rejected. The water cools as the heat is extracted by the refrigerant, this "chilled water" is then pumped around the building to provide air conditioning, This "Chilled water" then returns to the evaporator bringing with it any unwanted heat from the building.
6) *Water Boxes:* Water boxes are mounted to the evaporators and also the condensers of water cooled chillers. The purpose of the water box is to direct flow as well as as to segregate the entrance and exit. Depending on the number of passes in the evaporator and condenser, water boxes may have 1-2 flanged entrance or exit holes or they can be completely capped and just redirect flow back into the next pass.
7) *Capillary Tube:* Capillary tube is one of the most commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration and air conditioning applications.

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III. NANOPARTICLE

According to the International Standards Organization (ISO) technical specification 80004, a nanoparticle is an object with all three external dimensions in the nano scale, whose longest and shortest axes do not differ significantly, with a significant difference typically being a factor of at least 3. In its 2012 proposed terminology for biologically related polymers, the IUPAC defined a nanoparticle as "a particle of any shape with dimensions in the 1×10^{-9} and 1×10^{-7} m range". This definition evolved from one given by IUPAC in 1997. In another 2012 publication, the IUPAC extends the term to include tubes and fibers with only two dimensions below 100 nm.

Nanoparticles with one half hydrophilic and the other half hydrophobic are termed Janus particles and are particularly effective for stabilizing emulsions. They can self-assemble at water/oil interfaces and act as solid surfactants. Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. The properties of materials change as their size approaches the nano scale and as the percentage of atoms at the surface of a material becomes significant.

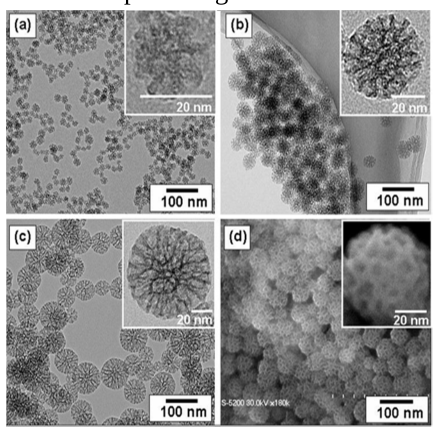

Fig 3.1Nanoparticle

A. *Use Of Nanoparticles In Air Conditioning System*

Though nanotechnology has been making waves in the world of science and technology for some time now, its use in consumer products has only recently started making waves.

Nanoparticles can be used in air conditioning systems because of its remarkable improvement in thermo- physical and heat transfer capabilities to enhance the performance of air conditioning systems.

B. *Zinc Oxide As Nanoparticle*

Zinc oxide nanoparticles are nanoparticles of zinc oxide (ZnO) that have diameters less than 100 nano meters are shown in Fig 4.2 zinc oxide Nano Particle. They have a large surface area relative to their size and high catalytic activity. The exact physical and chemical properties of zinc oxide nanoparticles depend on the different ways they are synthesized.

ZnO nanoparticles are believed to be one of the three most produced nano materials, along with titanium dioxide nanoparticles and silicon dioxide nanoparticles. The most common use of ZnO nanoparticles is in sunscreen. They are used because they reflect ultraviolet light, but are small enough to be transparent to visible light.

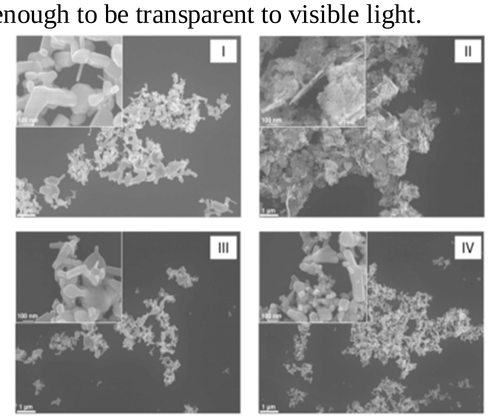

Fig 3.2 Zinc oxide

They are also being investigated to kill harmful microorganisms in packaging, and in UV-protective materials such as textiles. Many companies do not label products that contain nanoparticles, making it difficult to make statements about production and pervasiveness in consumer products.

C. Applications

ZnO include the manufacture of rubber and cigarette filters; calamine lotion and creams and ointments used to treat skin diseases; an additive in the manufacture of concrete and ceramics; food products such as breakfast cereals; and as a coating agent in various paints.

D. Advantage of Using ZnO

Use of ZnO in chilled water air conditioning system to increase the heat transfer, cooling rate of the system and improve the overall system performance. It gives more cooling effect to the surrounding, machineries and make as a human comfort.

IV. LITERATURE REVIEW

R. Parameshwaran, S. Kalaiselvam The thermal performance and energy efficiency of chilled water based variable air volume air conditioning system integrated with the silver nanoparticles embedded latent thermal energy storage system. The latent thermal energy storage air conditioning system incorporated with building air conditioning application. Phase change material embedded with silver nanoparticles enabled it to exhibit improved heat transfer mechanisms. Experimental results suggest that the proposed air conditioning system achieved an on-peak and per day average energy savings potential of 36–58% and 24–51%, respectively, for year round operation while compared to the conventional air conditioning system.

M. Salem Ahmeda, Elsaid Ashraf Mimib In this work, the performance characteristics of a vapor compression refrigeration system associated with a chilled water air conditioning unit utilized nano fluids (Al_2O_3, TiO_2, and a hybrid of Al_2O_3/TiO_2 based H_2O) were experimentally investigated. The study incorporated different concentration ratios of nanoparticles Al_2O_3/H_2O, TiO_2/H_2O, and concentrations of hybrid nanoparticles Al_2O_3/TiO_2. Experimental results indicated that the single nano fluid of Al_2O_3/H_2O contributed a higher coefficient of performance and a lower elapsed time for cooling the fluid of a chiller system.

The Al_2O_3/H_2O provided lower values of compression ratio and higher values of the refrigeration effect in comparison with TiO_2/H_2O by approximately 4.1% and 5.3%, respectively.

Amrat Kumar Dhamneya, S.P.S.Rajput, AlokSingh The nanoparticle is used in chillers for increasing system performance. The increasing concentration of nanoparticles (TiO_2) in refrigerant increases the performances of the system due decreasing compressor work done and enhance heat transfer rate. In this article, vapour compression refrigeration system coupled with evaporative cooling pad, and nano-refrigerant, for improving the performance of the system. . The experimental investigations revealed that the performance characteristics of the evaporatively-cooled condenser are significantly enhanced. Maximum C.O.P. increases by about 51% in the hot and dry climate condition than the normal system.

V. METHODOLOGY

The experimental unit of Fig 5.1 Flow diagram of chilled water air conditioning has consisted of two loops for circulation of two base fluids (refrigerant and nano fluids/chilled water) in which the evaporative (cooling tank) is the intermediate element for the two loops. The first loop, is the circulation of nano fluids/chilled water (the first base fluids) and it composes of the cooling tank and the cooling coil at which the incoming air to be cooled.

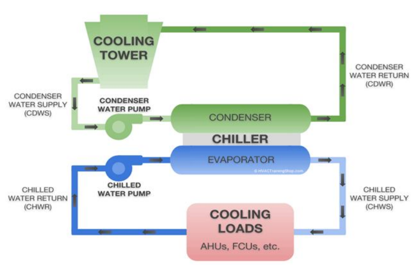

Fig 5.1 Flow diagram of chilled water air conditioning system

The second loop is the vapor refrigeration compression system at which the refrigerant (second base fluid) was circulated through the evaporative (cooling tank) causing the cooling effect.

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A. Nanofluids

Nanofluids are a mixture of zinc oxide ZnO, nanoparticles of weight fraction with the water base fluid (chilled water). Concentrations of zinc oxide nanoparticles are prepared and added to the water base fluid to study the effect of concentration in case on the performance of the systems with and without adding to the water base fluid.

1) *Zinc Oxide Nanoparticles:* Zinc oxide is an odorless, Fig 5.2 Zinc oxide powder that is naturally occurring in the mineral zincite. Because of its insolubility in water, zinc oxide has a number of practical uses and is commonly found in ceramics, pigments, foods, and first-aid tapes. It is found that the size of zinc oxide nanoparticles ranges of 20-100 nm. Samples of zinc oxide nanoparticles were prepared a concentrations by weight fraction.

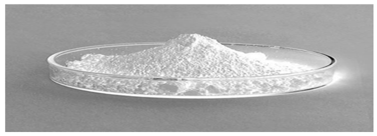


Fig 5.2 Zinc oxide powder

B. Measurements And Techniques

Various measurements have been performed to obtain the performance of the chilled water air conditioning unit under different operating conditions. These measurements have been included measuring the temperatures and flow rate of air and fluid at different positions. They were T1,T2 at inlet and outlet of air through the fan coil , T3, T4 inlet and outlet of chilled fluid (water or nanofluid) and T5, T6 of the refrigerant at the inlet and outlet of the evaporative (the cooling tank) respectively using thermometer for fluid. The volume flow rate of air is measured by using anemometer.

C. Working Principle

First, to test the unit for operation with no load, then the unit operates with supply the evaporative (cooling tank) with water and the vapour compression system is running at the same time where the flow of refrigerant is coming to the evaporative to cooling the water. To record the temperatures at different locations from time at 9.30 am to 10.30 am at repeated interval 15 mins. The run was performed at constant volume flow rate of chilled water to the cooling coil and also constant volume flow rate of coming air to the cooling coil. The experiments have been conducted by the volume flow rate of chilled water 8.5Lit/min and recording the reading of temperatures in each run system of chilled water air conditioning unit. The whole system Fig 5.3 Working of chilled water air conditioning system with and without nanoparticle is mainly composed from the chilled water unit which was consisted from the cooling tank filled with base fluids, cooling coil and the system of vapour compression system. The zinc oxide nanoparticle of a specified concentration was mixed with the water inside the cooling tank (evaporative) after starting the unit to ensure good mixing of nanoparticles of zinc oxide with water during the operation of the cycle. To maintain a continuously colloidal of nano fluids, the return chilled water from the cooling coil to the evaporative is poured at the near of bottom of the cooling tank.

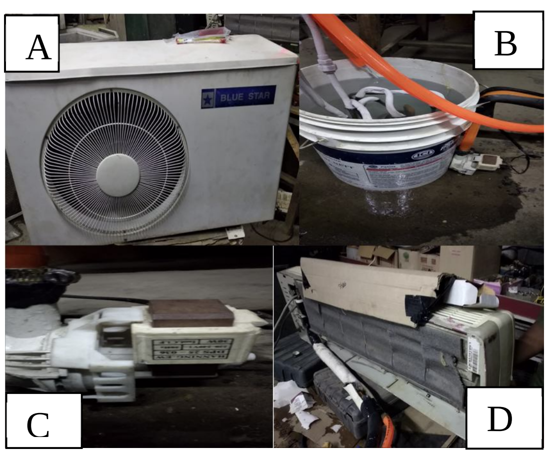


Fig 5.3 Working of chilled water air conditioning system with and without nanoparticle

The experiment was run at concentration of nanoparticles of zinc oxide by weight and operating conditions of volume flow rates of zinc oxide nano fluids (base fluids for 8.5Lit/min. For each run, the different reading was recorded to calculate the performance of the chilled water air conditioning unit.

VI. CALCULATION AND RESULT

A. *Overall Performance*

Reading Without nanoparticle

Time	Evaporator Outlet $T_1(^0C)$	Condenser Inlet $T_2(^0C)$	Condenser Outlet $T_3(^0C)$	Evaporator Inlet $T_4(^0C)$	COP
9.30AM	19	40	30	16	5.76
9.45AM	17	42	31	13	5.80
10.00AM	16	44	32	11	5.86
10.15AM	15	45	35	9	6.10
10.30AM	14	43	36	7	6.16

Reading With Nanoparticle

Time	Evaporator Outlet $T_1(^0C)$	Condenser Inlet $T_2(^0C)$	Condenser Outlet $T_3(^0C)$	Evaporator Inlet $T_4(^0C)$	COP
9.30AM	17	42	33	14	5.97
9.45AM	15	44	34	12	6.01
10.00AM	14	45	35	10	6.16
10.15AM	13	47	37	8	6.23
10.30AM	12	46	39	6	6.38

B. *Chiller Performance*

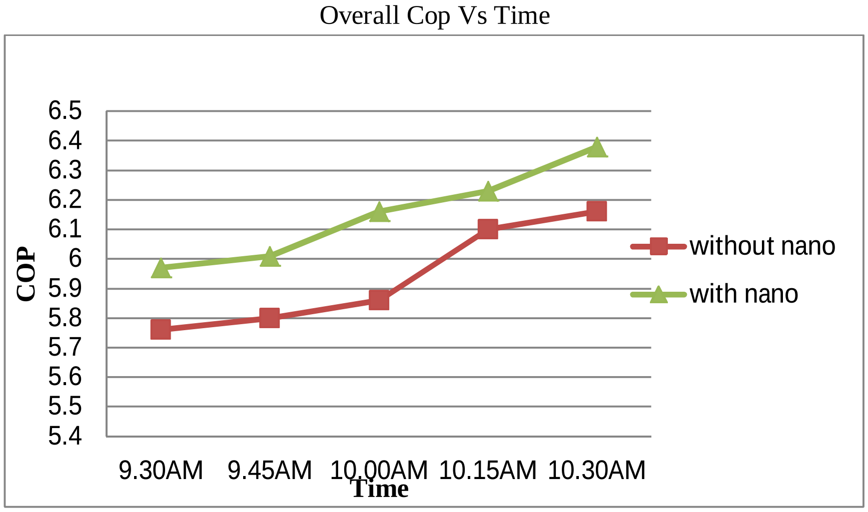
Reading Without Nanoparticle

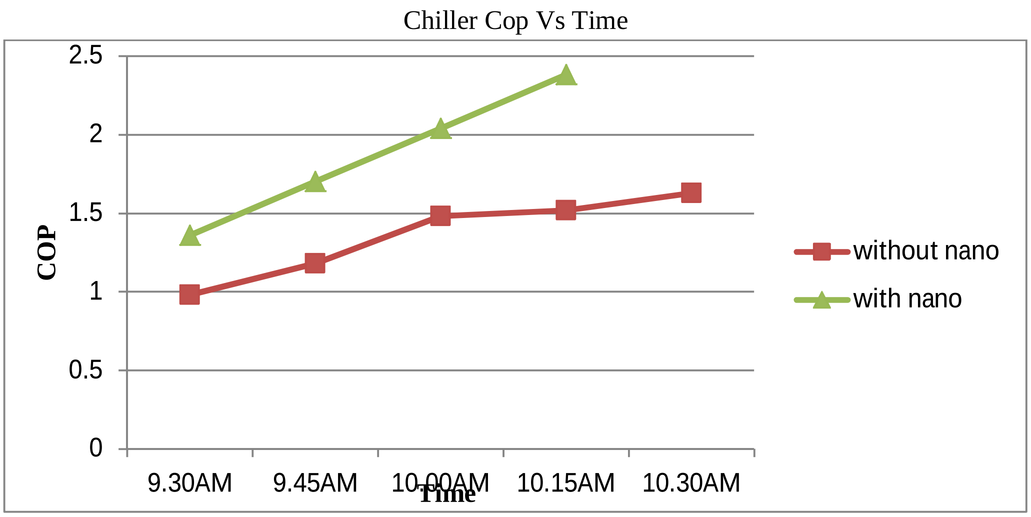
Time	Ambient Temperature $T_1(^0C)$	Room Temperature $T_2(^0C)$	Chiller Outlet $T_3(^0C)$	Chiller inlet $T_4(^0C)$	Evapora-tor outlet $T_5(^0C)$	Condens-er outlet $T_6(^0C)$	COP
9.30AM	29	28	16	19	19	30	0.98
9.45AM	29	28.7	13	17	17	31	1.18
10.00AM	30	29	11	16	16	32	1.48
10.15AM	31	29.8	9	14	15	35	1.52
10.30AM	32	29	7	12	14	36	1.63

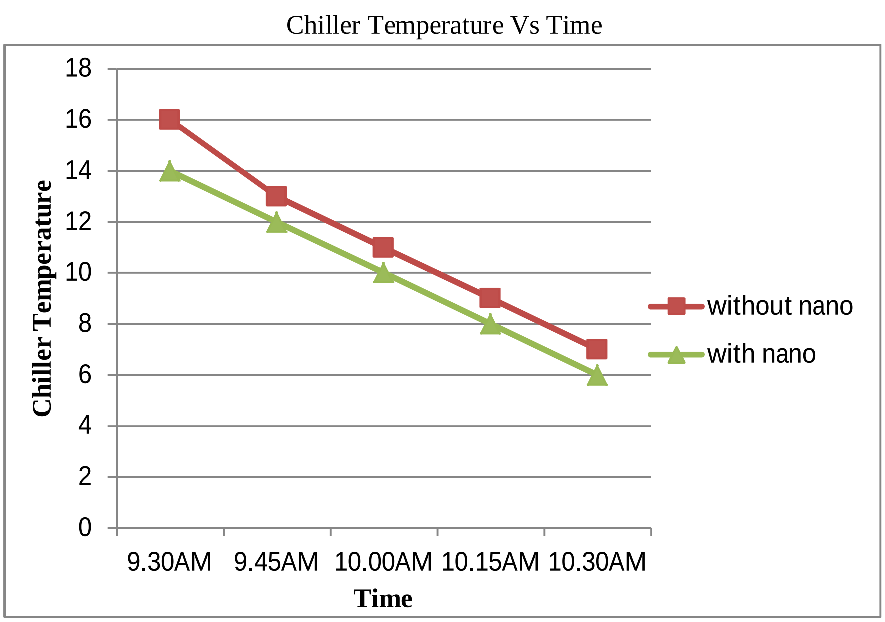
Reading With Nanoparticle

Time	Ambient Temperature $T_1(^0C)$	Room Temperature $T_2(^0C)$	Chiller Outlet $T_3(^0C)$	Chiller inlet $T_4(^0C)$	Evapora-tor outlet $T_5(^0C)$	Conden-ser outlet $T_6(^0C)$	COP
9.30AM	28	27	14	17	17	33	1.02
9.45AM	29	27.6	12	16	15	34	1.36
10.00AM	31	28	10	15	14	35	1.70
10.15AM	32	28.7	8	14	13	37	2.04
10.30AM	34	29	6	13	12	39	2.38

C. Comparision Charts







VII. CONCLUSION

The thermal performance of chilled water air conditioning unit has been investigated with zinc oxide nano fluids. The experiments have been performed through the flow rate of the working fluids (zinc oxide nano fluids and pure water) 8.5 Lit/min. An improvement of the heat transfer characteristics of the working fluids (pure water) has been achieved by addition of zinc oxide nanoparticles to the pure water. This is revealed from the results of reduced the elapsed time required to cool the zinc oxide nano fluids comparing to the elapsed time of the pure water by about half hour for most the concentrations of zinc oxide nanoparticles. With increasing the flow rate of the working fluids (zinc oxide nano fluids), the elapsed time also reduced to the required temperature to be re circulated. Also, it is noticed that with increasing the concentrations of zinc oxide nanoparticles, the elapsed time has been reduced. Preparation of homogeneous suspension of nanoparticles and base fluids still a technical challenge to obtain a continuous colloidal during the cycle of nanofluids. The flow rate of base fluids (zinc oxide nano fluids/chilled water) and the incoming air to be cooled have been a significant effect on elapsed time for cooling the base fluids. It is also noticed that the cycle of cooling the air using zinc oxide nanoparticles operates with normal manner like the cycles with pure water only.

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