

## PERFORMANCE ENHANCEMENT OF AN AIR-CONDITIONING SYSTEM BY USING HEAT PIPE – A REVIEW

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### Abstract

Heat pipe is a simple heat transfer device that acts by transferring heat from evaporation section to the condensation section. Besides, the heat pipe mechanism is using the natural convection to absorb heat from evaporator sector and release the heat at the condenser sector which the latent heat of vaporization is utilised with a corresponding small temperature different. In the last four decades many researchers have studied many parameters related to Heat Pipe used in HVAC System. In this paper we have studied type of heat pipe, type of fluid, heat exchanger surface, thermal performance of a heat pipe charged with nanofluids, Thermophysical properties of the heat pipe material and the working fluid, effect of the heat transfer rate on overall thermal conductivity of heat pipe, effect of the Heat Transfer coefficient of heat pipe. We have studied advantages and disadvantages heat pipe exchangers in HVAC systems. The main advantage by using a heat pipe is that large quantities of heat can be transported through a small cross-sectional area over a considerable distance with no additional power input to the system.

### 1. Introduction

#### 1.1 Summer Air Conditioning System

When the air is hot and wet, relative humidity is high, treating of the air in the air conditioning system differs from the system used for hot and dry air. This is because air contains more quantity of water vapour than required; it is necessary to remove the water from the air by dehumidification.

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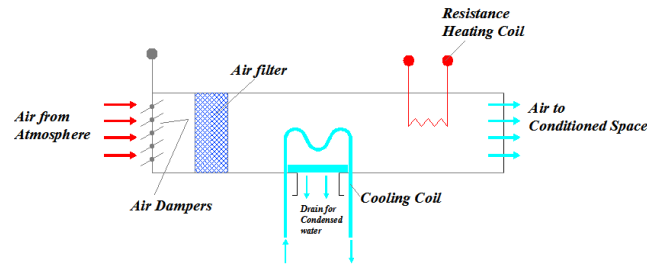
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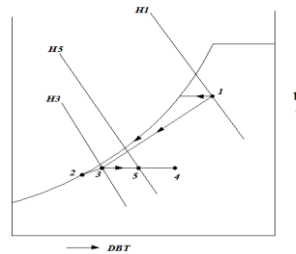
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**Fig.1:** Schematic of Summer Air-Conditioning System for Hot and Wet Weather

Suppose the average summer conditions are  $32^{\circ}\text{C}$  DBT and 75% relative humidity. The required comfort conditions are  $24^{\circ}\text{C}$  DBT and 60% RH. The arrangement of the equipment required is as shown above.



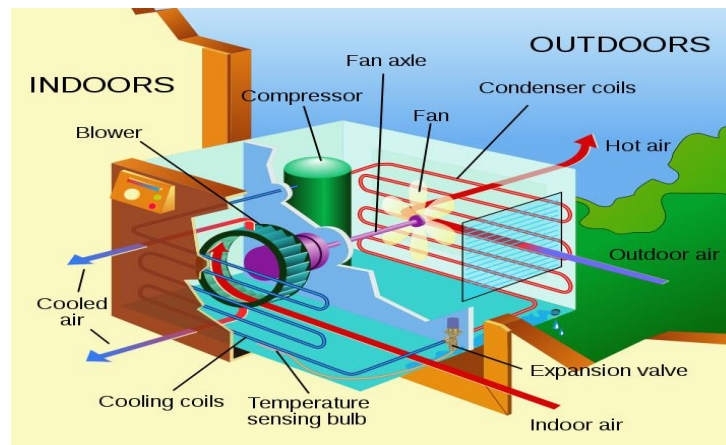
**Fig. 2:** Psychrometric chart for system

The air at first is passed through air filter to remove the dust and then it is passed over the cooling coil. The water vapour is removed from the air in the form of water droplets as air is cooled below its dew point temperature (DPT). Surface temperature of the cooling coil is always maintained below DPT of the outdoor air to accomplish de-humidification. The quantity of water removed from the air is controlled by controlling the cooling coil surface temperature. The cooling coil surface temperature is controlled by controlling the quantity of coolant passed through the cooling coil. The temperature of air leaving the cooling coil is considerably lower than the required temperature for comfort (state 3). The air coming out from the cooling coil is passed over heating coil and heated upto required temperature. Temperature of air is controlled by controlling the resistance of the heating coil as per type of heating used. The air coming out from the heating coil at required condition is supplied to the air-conditioned space (state 5). The quantity of air passed through the air conditioning space is controlled with the help of air dampers as per load in the air conditioning space.

## 1.2 Air Conditioning System

An air conditioner is a home appliance, system or mechanism designed to dehumidify and extract heat from an area. The aim of distributing the conditioned air to an occupied space to improve thermal comfort and indoor air quality. The cooling is done using a simple refrigeration cycle i.e.

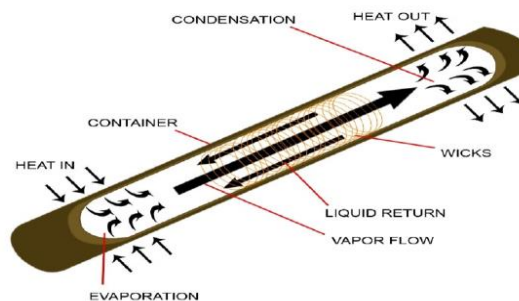
Simple vapour compression cycle. In construction, a complete system of heating, ventilation, and air conditioning is referred to as "HVAC". Its purpose in a building or an automobile is to provide comfort during either hot or cold weather. The coils and pipes in an air conditioning unit contain refrigerant gas. The refrigerant gas enters the compressor as warm, low-pressure gas and leaves it as hot, high-pressure gas. In the condenser coils hot compressed refrigerant gas loses heat to the outdoor air and becomes liquid while it is still warm. The warm liquid refrigerant passes through the tiny opening of the expansion valve, expands and partly turns to gas at a low temperature. In the cooling coils the refrigerant takes up heat from the indoor air and leaves the coils as warm, low-pressure gas.



**Fig.3.** Different Parts of an Air Conditioning Unit

The indoor air gives up heat to the refrigerant in the cooling coils and also loses moisture as it is chilled. The moisture condenses on the coils and trickles down to outside drain holes. Cooled air is blown back into the room. For residential homes, some countries set minimum requirements for energy efficiency. In the United States, the efficiency of air conditioners is often (but not always) rated by the seasonal energy efficiency ratio (SEER). The higher the SEER rating the more energy efficient is the air conditioner.

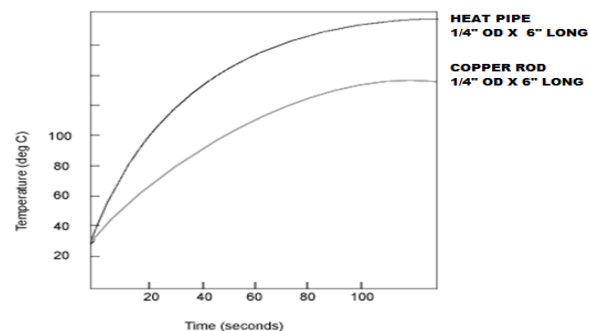
### 1.3 Heat Pipe:



**Fig.4.** A schematic of Heat Pipe

A heat pipe is a high-performance heat transfer device which is used to transfer a large amount of heat at a high rate with a small temperature difference. When heat is added to the evaporator section the working fluid boils and converts into vapour absorbing latent heat after reaching the condenser section due to partial pressure build up the vapour transforms back into liquid thus releasing latent heat. From the condenser section heat is taken away by means of air cooling with fins etc. The liquid condensate returns to the original position through the capillary return mechanism completing the cycle. Due to very high latent heat of vaporization a large quantity of heat can be transferred shown in Figure.

Simple design and flexibility of heat pipes are important reasons for their extensive applications in industries and air conditioning. Heat Pipe is an evacuated sealed tube with a capillary mechanism incorporated for the return of working fluid. The idea of heat pipes was presented first by Gaugler in General Motor Company in 1942. The first heat pipe was designed and manufactured by Grover in National Lab, Los Alamos, in the US in 1964. Since then, heat pipes are being used in many applications such as heat exchangers (air pre-heaters or systems that use economizers for waste heat recovery), cooling of electronic components, solar energy conversion systems, spacecraft thermal control, cooling of gas turbine rotor blades, etc. Because of heat transfer mechanism in heat pipes is carried out through boiling and condensation the effective thermal conductivity of heat pipe exceeds that of copper 200 to 500 times. If one inch of test sample immersed in boiling water heat sink the following results are obtained as shown in below fig.5.



**Fig.5.** Thermal Response with time graph of Heat Pipe V/s Copper rod

Heat pipes can dramatically improve the moisture removal capabilities of many air-conditioning systems yet actually lower power bills at the same time. Air can be precooled by simply transferring heat from the warm incoming air to the cool supply air. This bypassing can be accomplished by placing the low end of a heat pipe in the return air and the high end in the supply air. Heat is removed from the warm upstream air and rerouted to the cool downstream air. This heat in effect bypasses the evaporator although the air that contained the heat does indeed pass through the AC coil. The total amount of cooling required is slightly reduced and some of the air conditioners sensible capacity is therefore exchanged for additional latent capacity. Now the unit can cope with high-moisture air more efficiently. To accomplish a heat transfer around a cooling coil through utilization of heat pipe technology, different configurations may be used. One method is to arrange several heat pipes in parallel banks with the evaporator coil separating the pipes evaporator ends

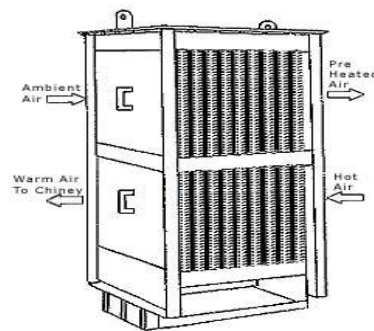
and condenser ends. Fins may then be attached to the outside surface of the heat pipes to improve the heat transfer between the tubes and the air. After a heat pipe system has been installed, most vendors will use a vacuum pump, evacuate the heat pipes to less than 50 microns of air and then partially fill them with a working fluid, usually HCFC22. The pipes then will be hermetically sealed and affixed to your air-conditioning unit. It is important that no service valves be left on the pipes. At least one vendor however, supplies prepackaged heat pipe systems with the pipes already partially filled and sealed. A highly effective air-to-air heat exchanger has now been created. The result is that the air conditioners latent cooling capacity has now been increased. The air supplied to the building is drier than that provided by the air conditioner alone.

### 1.3.1 Heat Pipe Heat Exchangers:

Heat Exchanger is a device in which two fluid stream one hot one cold are brought into thermal contact to effect transfer of heat from hot fluid stream to cold. It provides relatively large area of heat transfer for given volume of equipment. Types of Heat Pipe Heat Exchangers:

#### I) Air to air Heat Pipe Heat exchangers:

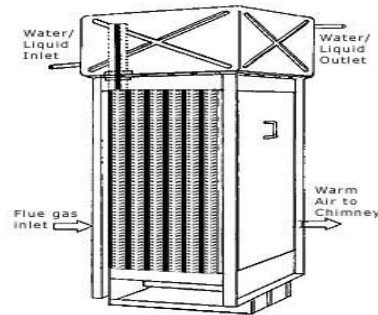
Typical finned air to air Heat Pipe heat exchangers comprises of number of tubular gravity assisted finned Heat Pipes arranged in staggered pitch depending upon the application. One of the advantages of the Heat Pipe Heat Exchanger is its ability to operate without cross contamination between the two gas streams. Use of Gravity Assisted Heat Pipe complies orientation evaporator above condenser for the Heat Pipe Heat Exchanger.



**Fig.6.** Air to air Heat Pipe Heat exchanger

#### II) Air to liquid Heat Pipe Heat exchangers:

This heat exchanger resembles Air to Air unit only difference is liquid/water tank is provided at the condensation section to preheat liquid/water.



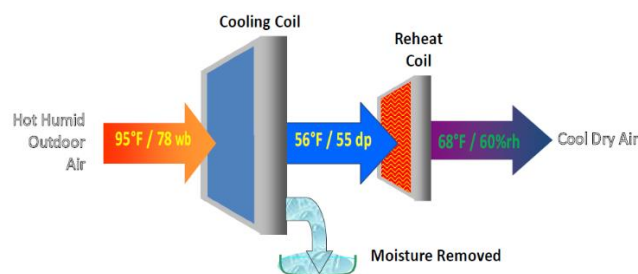
**Fig.7.** Air to liquid Heat Pipe Heat exchangers

#### 1.4 Dedicated Outside Air System (DOAS):

A dedicated outside air system (DOAS) is a type of heating, ventilation and air-conditioning (HVAC) system that consists of two parallel systems, a dedicated outdoor air ventilation system that handles latent loads and a parallel system to handle sensible loads. Outside-air requirements now specify ventilation effectiveness at the occupant level as well as airflow at the system level. Conventional mixed-air variable-air-volume systems sometimes are proving inadequate for humidity control while effectively ventilating with verifiable outside-air quantities. A particularly successful design approach is to treat and distribute outside ventilation air with separate equipment and ductwork i.e. DOAS. A DOAS is designed to satisfy 100 percent of the outside-air ventilation requirements established by ASHRAE and using outside air and heat pipe technology the DOAS system eliminates the need of a dedicated heating coil for heating purpose.

DOAS designs can provide the following operating characteristics:

1. Capacity to modulate the dew point of the conditioned outside air so the entire building latent load (ventilation-air latent load plus internal latent loads) is satisfied by the DOAS. A recirculating HVAC system handles only the remaining building sensible-cooling load.
2. DOAS helps reducing electric power consumption of the electric heater.
3. DOAS employs heat pipes made from copper. Hence no corrosion problems.
4. DOAS reduces the maintenance and running cost.



**Fig. 8.** Dedicated outside Air System with Reheat coil

## 2. Literature Review

Stanley A. Mumma studied Integration of dedicated outdoor air (OA) systems with A parallel terminal system represents a huge shift in the standard engineering design paradigm. This paper will present some of the issues that guided the migration path toward separate Dedicated OA ventilation systems and away from delivering the ventilation via single all-air variable air volume systems. separating the OA system from the space-conditioning systems to ensure proper ventilation in all occupied spaces, conditioning the OA to handle all of the space latent load and as much of the space sensible load as is economically feasible without excessive reheat, maximizing the cost-effective use of energy recovery equipment, integrating the fire suppression and energy transport systems and employing radiant ceiling heating and sensible cooling for occupant thermal control where appropriate [1]. Kurt M. Shank concluded that, the DOAS supply air conditions have been addressed in this paper. Currently, nearly all systems employing dedicated OA systems supply air at or near neutral thermal conditions. The intent of this paper was to challenge that practice. At the outset of the paper, three hypotheses were advanced. The first hypothesis predicted that for a given supply air dew-point temperature, supply air dry-bulb temperatures below neutral would result in both a lower first and operating energy costs. That hypothesis was confirmed. Based upon the results presented, combining a low SAT and a low DPT provides the best first and operating cost option. The second hypothesis predicted that for a given supply air dry-bulb condition, supply air DPTs that would provide space relative humidity around 40% RH would result in lower first and operating expenditures than higher supply air dew-point temperatures. That hypothesis was also confirmed. The third hypothesis predicted that with supply air dry-bulb temperatures lower than neutral, i.e., 55°F (13°C) or less, minimal or no terminal reheat would be required for many building applications. That hypothesis was also confirmed, and the reasons explored [2]. Timothy P. McDowell studied the Dedicated outdoor air systems (DOAS) to treat the outdoor air before it enters the building and thus reduce the load on the zone equipment. This paper presents a study of different DOAS configurations and their energy and power consumptions for multiple climates of different cities like Bismarck, Minneapolis, St. Louis, Phoenix, and Miami in the United States. The building modeled in this study is a two-story office building with a total floor area of 2250 m<sup>2</sup>. For this study four different HVAC systems model is used i.e. Baseline system, Baseline with Economizer system, Simple DOAS system, and Full DOAS system. According to the result the simple DOAS resulted in savings in Energy cost ranging from 14 % to 37 % and the full DOAS in slightly higher savings in Energy cost ranging from 21 % to 38 %. Hence both the simple and full DOAS show promise in reducing the energy consumption of the HVAC system in the office buildings in all the climates [3].

Mostafa A. Abd El-Baky had experimentally studied the heat pipes heat exchangers are used in heat recovery applications to cool the incoming fresh air in air conditioning applications. Two streams of fresh and return air have related to heat pipes heat exchanger to investigate the thermal performance and effectiveness of heat recovery system. Fresh air inlet temperature of 32-40°C has been controlled while the inlet return air temperature is kept constant at about 26°C. Ratios of mass flow rate between return and fresh air of 1, 1.5 and 2.3 have been adapted to validate the heat transfer and the temperature change of fresh air. The experimental study showed the following result that the temperature changes of fresh air, hot, and return air, cold are increased with increasing the inlet temperature of fresh air, The heat transfer and effectiveness for both evaporator and condenser sections are increased with increasing the fresh air inlet temperature, Increasing the return to fresh air mass flow rate ratios by about two times leads to increase the temperature change of fresh air about 20 % and effectiveness of the heat pipes heat exchanger by about 26 %, The effect of mass flow rate ratio on effectiveness is positive for evaporator side and negative for condenser side, The heat recovery is increased with increasing inlet fresh air temperature and attained about 85 % [4]. Ehsan Firouzfard studied the Heat Pipe Heat Exchangers Activity in Asia Humidity control is a never-ending war in tropical hot and humid built environment. Heat pipes are passive components used to improve dehumidification by commercial forced-air HVAC systems. They are installed with one end upstream of the evaporator coil to pre-cool supply air and one downstream to re-heat supply air. This allows the system's cooling coil to operate at a lower temperature, increasing the system latent cooling capability. Heat rejected by the downstream coil reheats the supply air, eliminating the need for a dedicated reheat coil. Yat H. Yau studied the studied an 8-row thermosyphon-based heat pipe heat exchanger for tropical building HVAC [5]. Ehsan Firouzfard studied the applications of wickless heat pipe heat exchangers in HVAC systems. There are three important criteria which relate to human comfort: temperature, humidity, and air motion. Comfort conditions for humans require a temperature of between 22 and 25, and relative humidity between 40% and 60%. Air leaving the cooling coils of an air conditioner is usually near dew point i.e. saturated, and its relative humidity can exceed 95%. Thus, a reheating coil is placed after the cooling coil to reheat the air and reduce the relative humidity, while keeping the temperature within the comfort range. S.H. Noie et al. investigated the effect of input air properties on the efficiency of an air conditioning system with wickless heat pipe heat exchanger at pilot scale. Mass flow, temperature and humidity were main design parameters of that air conditioning system. Their experiments showed that by using heat pipe heat exchanger in an air conditioning system, they can save around 10-15% of energy in the evaporator and 40-65% in the condenser of the heat pipe heat exchanger [6]. B.F. Yu [07] studied the research on air-conditioning systems and indoor air quality control for human health. Many kinds of AC systems are used to improve indoor thermal comfort and IAQ. Recent research is focused on dedicated outdoor air system (DOAS), independent control of temperature and humidity system (ICTHS), and cooling ceiling and displacement ventilation systems (CC/DV). With the occurrence of SARS, avian flu and anthracnose in some countries, the safety of AC systems becomes more important. DOAS, an effective measure to realize immune building, has gradually been appreciated by international AC industry. DOAS results in a significant revolution in air-

conditioning industry. DOAS is an all-air system without return air, and it eliminates intercrossing infection existing in all air system with return air. DOAS also exhibits better effect of energy saving. When the effectiveness of total heat exchanger is 65%, DOAS using CC as SHRTD can save the electric energy by 42%, compared with conventional VAV systems [7]. Dr. Michael K. West experimentally study Heat pipe wrap-around coils system and Dedicated Outside Air System (DOAS) to satisfy 100% outside air designs to help the designer meet ASHRAE Standards 62.1-2010 and 90.1-2010 in new buildings, and to improve HVAC performance, Indoor Air Quality (IAQ) and energy efficiency in existing buildings by increasing dehumidification and/or ventilation effectiveness. In this study Heat pipes reduce entering outside air temperature by 5 to 20 degrees F before it enters the cooling coil and provide 5 to 20 degrees F reheats downstream of the cooling coil with relatively little energy use. Heat pipes are passive, requiring a small amount of additional fan power to overcome the pressure drop through the heat pipe fin-tube coils. By pre-cooling the outside airflow entering the cooling coil, more water vapor is removed by the cooling coil, and the downstream reheat section produces supply air that is closer to neutral air conditions. [8]. Ehsan Firouzfar studied the application of heat pipe heat exchangers in heating, ventilation, and air conditioning (HVAC) systems. According to experimental results, the cooling capability for the system was improved by 20 to 32.7%. Based on the results, the application of this type of heat exchanger instead of conventional reheat coils resulting in energy saving and enhancing the cooling capability of the cooling coils was suggested. In this study, a LHP without wick in the form of a U shaped was used to heat the return air before passing cooling coil. Absorbed heat of return air was used for heating fresh air before passing electrical heater. Therefore, energy savings both in cooling and heating were achieved. The working fluid used in this study was R-134a and thermal effectiveness coefficient of the heat pipe dehumidifier was 0.31 [9]. E. Firouzfar investigates the heat pipe heat exchanger effectiveness and energy saving in air conditioning systems using silver nanofluid. The present study attempts to use the methanol– silver nanofluid filled heat pipe heat exchanger and compares the effectiveness as well as the energy saving with pure methanol. For this study the heat exchanger had 36 plates finned copper thermosyphons arranged in three rows was used. The nanofluid used in the present study is 20 nm diameter silver nanoparticles. The experiments were performed to compare the heat pipe heat exchanger effectiveness and energy saving, using nanofluid and pure methanol [10]. M. Ahmadzadehtalatapeh studied Based on field measurements; it was found that air conditions provided by the existing AC system are not within the thermal comfort zone recommended by the ASHRAE. Therefore, the possibility of enhancing system performance in terms of provided air conditions and power consumption was studied. To achieve more reliable simulation results, the effectiveness of three fabricated HPHEX with a different number of rows was experimentally obtained under conditions like actual conditions in terms of evaporator inlet air, coil face velocity, and inside temperature. TRNSYS software was employed to simulate the performance of existing AC systems and the system equipped with the HPHEX for the entire year. Based on simulation results, system performance was significantly improved with the added HPHEX [11]. K. Vaseemul Rahaman studied the application of computer fluid dynamics for optimization of air conditioning equipment. Computer fluid dynamics (CFD)

analysis is a recent achievement of CAE technology that is finding growing application in the air conditioning field to enable such concurrent development to be performed through simulation. To date, CFD has mainly been used by air conditioner manufactures to analyze the airflow of air conditioners in isolation, or by automotive manufactures to analyze defroster performance and interior airflows; in other words, it has been applied most frequently to in cabin component layout and event analyses. CFD simulation can be used as an effective and economical tool to produce valuable guidance for practical improvements to the processing air-conditioning systems in industrial buildings [12]. Tushar S. Jadhav investigates the possible energy savings using HPHX for heat recovery in air conditioning system for a process air conditioning facility in Pune city, India. He studied the air conditioning load analysis with and without HPHX. He also studied the effect of number of rows of HPHX on the maximum savings in cooling coil capacity for the base case condition with HPHX according to comparison to the base case condition, he see that there is a saving of more than 3 TR on cooling coil capacity when HPHX with 4 or more rows is installed [13]. K. S. Ong reviewed the heat pipe heat exchangers for enhanced dehumidification and cooling in air conditioning systems. Beckwith proposed two novel applications of HPs in air Conditioning systems. The first involves a WHPHE system, with precooling and reheat of the supply air. The second application involves the addition of a HPHE with a conventional subcooling and de-superheating heat exchanger coil to provide additional reheat in a controlled manner to provide humidity control at low cooling load conditions. Their simulations showed the proposed systems could economically control humidity and improve indoor air quality. Intake air was heated with an electric heater and humidified by steam generated in an electric boiler [14]. R. Manimaran studied the various parameters that affect the operational characteristics of circular heat pipe. Moreover, the thermal resistance and heat transfer capability are affected by the choice of working fluid, the tilt angle, the fill ratio, thermal properties, and heat input. He concluded that the heat pipe shows greater enhancement in heat transfer when the filling ratio is 40% to 85%. The wick structure has a dominant effect on the heat pipe performance which provides capillary pressure difference for the liquid–vapour flow between evaporator and condenser sections. The fluid selection mainly depends on the operating vapour temperature range; also, the primary requirements such as compatibility of the fluid with the heat pipe material should be considered. Many articles reveal that nanofluids have greater potential for improving the thermal efficiency of the heat pipe. The orientation of the heat pipe is important for the practical applications: favorable tilt and adverse tilt. It is preferable to operate heat pipe in a favorable tilt position so that heat transfer capacity can be increased [15].

### **3. Materials and Methods**

#### **3.1 Selection of Heat Pipe:**

A heat pipe is an evaporation-condensation device for transferring heat in which the latent heat of vaporization is exploited to transport heat over long distances with a corresponding small temperature difference. Selection of Heat pipe mainly depends on the temperature carried from Heat

source to heat sink i.e. heat can be absorbed on the evaporator region and transported to the condenser region where the vapour condenses releasing the heat to the cooling media. The operating temperature in case of Air conditioning system with DOAS is 0<sup>0</sup>C to 20<sup>0</sup>C.

Selection of heat pipe depends on following characteristics:

- a. Determine the working fluid appropriate for your application
- b. Select pipe material compatible to the working fluid
- c. Select wick structure for the operating orientation
- d. Decide on the protective coating
- e. Angle of Tilt

### 3.1.1 Benefits Heat Pipe:

Improved comfort level, moisture reduced, improved air quality, existing systems easily retrofitted, no moving parts, no additional energy required to operate, reduces hvac load by 22% and new installations pay back in less than 2 years

**Table 1.** Typical Operating Characteristics of Heat Pipes

Temperature Range (°C)	Working Fluid	Vessel Material	Measured axial <sup>8</sup> heat flux (kW/cm <sup>2</sup> )	Measured surface <sup>8</sup> heat flux (W/ cm <sup>2</sup> )
-200 to -80	Liquid Nitrogen	Stainless Steel	0.067 @ -163°C	1.01 @ -163°C
-70 to +60	Liquid Ammonia	Nickel, Aluminum, Stainless Steel	0.295	2.95
-45 to +120	Methanol	Copper, Nickel, Stainless Steel	0.45 @ 100°C <sup>x</sup>	75.5 @ 100°C
+5 to +230	Water	Copper, Nickel	0.67 @ 200°C	146 @ 170°C
+190 to +550	Mercury +0.02% Magnesium +0.001%	Stainless Steel	25.1 @ 360°C <sup>+</sup>	181 @ 750°C
+400 to +800	Potassium	Nickel, Stainless Steel	5.6 @ 750°C	181 @ 750°C
+500 to +900	Sodium	Nickel, Stainless Steel	9.3 @ 850°C	224 @ 760°C
+900 to +1,500	Lithium	Niobium +1% Zirconium	2.0 @ 1250°C	207 @ 1250°C
1,500 + 2,000 4.1 413	Silver	Tantalum +5% Tungsten	4.1	413

### 3.2 Selection of wick structure:

There are four common wick structures used in commercially produced heat pipes groove, wire mesh, powder metal, and fiber/spring. Each wick structure has its advantages and disadvantages.

There is no perfect wick. Sintered copper powder metal wick structure is used. The steps used to produce the sintered and mesh wick structures are detailed below. The sintered wick structure was made from pure red copper powder having particle size ranging between 200 and 350  $\mu\text{m}$  grades. 20 mm of copper powder was mixed with 20% (4  $\text{mm}^3$ ) of sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) that acts as a binder to ensure the adhesion of the wick to the copper pipe wall. A mandrel with an end cap was inserted in the copper pipe to leave a central vapor channel open. The powder with the binder was then placed in the annulus between the mandrel and the pipe and compacted to eliminate any gross cavities in the wick. The pipe, the powder and the mandrel were then heated in an electric furnace at 850  $^\circ\text{C}$  for  $\frac{1}{2}$  hour. Then, the pipe was cooled and the mandrel was removed.

### 3.3 Angle of Tilt:

The heat pipe efficiency increases with increasing tilt angle because the gravitational force has a significant effect on the flowing of working fluid between evaporator section and condenser section. However, when the heat pipe inclination angle exceeds  $30^\circ$  for de-ionic water and  $45^\circ$  for copper nanofluid and copper nanofluid with aqueous solution of n-Butanol, the heat pipe thermal efficiency tends to decrease.

## 4. EXPERIMENTAL STUDY:

Experimental study of heat pipe heat exchanger with dedicated outside air system to determine temperature gradient, coefficient of performance of system, energy of reheating, saving in energy cost and life cycle cost of a window air conditioning system.

### 4.1 Experimental Set up:

The Experimental set up of Heat Pipe Heat Exchanger System is shown in fig. 5.1. The tests set up of basic window air conditioning system consist of compressor, condenser, Evaporator, Expansion device, Accumulator. A separate ductwork is constructed to treat and distribute outside ventilation air i.e. the Dedicated outside Air System (DOAS). A DOAS is designed to satisfy 100% of the outside air (OA) ventilation requirements, as established by ASHRAE 62.1, using a separate distribution system. The Air Conditioner system capacity is of 0.75TR

The HPHEX system as shown in Fig. 9 consists of two parallel heat pipes having length 500mm and Diameter 16mm. One section of the heat pipe is in the return air duct and the other section in the cool supply air. The cool supply air chills one section while the warm return air heats the other. Heat is transferred from the warm return air to the cool supply air. The heat pipe is provided with radial fins made up of aluminum to increase the heat transfer area. The wick structure is of sintered copper. The unit is equipped with a two blower of 6 watt installed before the cooling coil and opening of Dedicated outside air system ductwork. Thermostat is component of a control system

senses the temperature of Air-Conditioning system so that system's temperature is maintained near desire setpoint. The refrigeration unit is charge with refrigerant R134a.



1- A.C Body, 2- Heat Pipe-1, 3- Heat Pipe-2, 4- Thermostat, 5- Evaporator coil, 6- Radial fin, 7- Accumulator, 8- Expansion valve, 9- Condenser, 10- compressor, 11- Blower.

**Fig. 9.** Experimental set up of Air conditioning system

#### 4.2 Experimental Procedure:

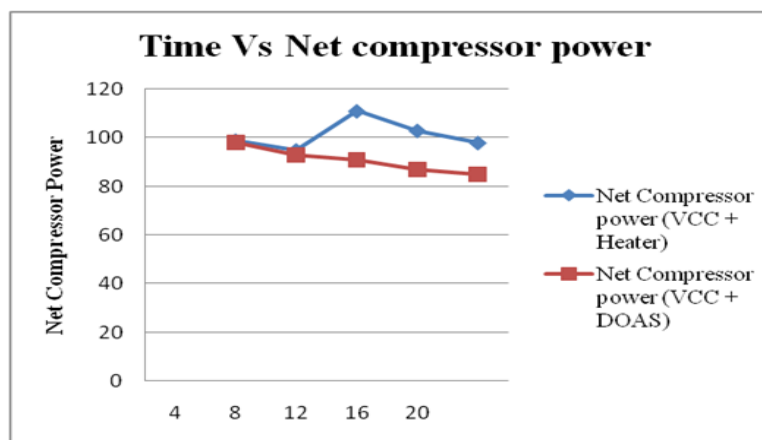
Mode I: Test and trial on conventional vapour compression cycle model with electric heater system.  
 mode ii: test and trial on conventional vapour compression cycle model with combine heat pipe and dedicated outside air system. The hot air and cold air temperature is measured by K-type thermocouple after the time interval of four minutes. Mass flow rate of Air is Constant. Inlet air Properties is 32 °C and 70% Relative humidity and for these conditions de-humidification purpose cooling coil temperature to be maintained at 15°C. Surface temperature of the cooling coil is always maintained below dew point temperature of the outdoor air to accomplish de-humidification, thus temperature of air leaving evaporator coil is 15°C, which will be an uncomfortable temperature for human being and hence the air is reheated up to 24°C by electric heater in First mode and by heat pipe in second mode. The voltage and current are measured by digital ammeter and voltmeter to find compressor power required for window air conditioning.

**Table 2.** Observation Table of Mode-I

Time (min)	Mass of air (kg/s)	Initial Temp. (°c) (T1)	Final Temp (°c) (T2)	$\Delta T$ (°c)	Compressor Power (W)	Heater Power (W)	Net Comp power (W)
4	12	28	24	4	99	-	99
8	12	28	22	6	95	-	95
12	12	28	18	10	89	22	111
16	12	27	16	11	84	19	103
20	12	27	16	11	79	19	98

## 5. Results and Discussion

Comparative study of Vapour compression system with heater and vapour compression system with heat pipe and dedicated outside air system provides that average energy consumption of vapour compression system with heater per hour is 0.1024 kWh and average energy of vapour compression system with heat pipe and dedicated outside air system per hour is 0.0915 kWh. Total energy consumption per year of vapour compression cycle with heater module is 663.552 kW and total energy consumption per year of vapour compression cycle with heat pipe and dedicated outside air system module is 592.93 kW. The saving in energy per year is 70.622 kW. The energy cost per year of vapour compression system with electric heater is Rs.5308.41 and the energy cost per year of vapour compression system with heat pipe and dedicated outside air system is Rs. 4743.36. The savings in life cycle cost of vapour compression system by application of dedicated outside air system is 1815.05 Rs/year.



**Fig. 10.** Time vs net compressor power consumption at  $T_1=28$  °C

## 6. Conclusions

The experimental study of heat pipe and DOAS air conditioning system lead to following conclusion:

1. COP of the window air conditioning system increases with application of the heat pipe and dedicated outside air system.
2. The energy cost per year reduced because of replacement of electric heater with heat pipe and DOAS arrangement.
3. Use of heat pipe reduces the running cost and maintenance cost of window air-conditioning system.
4. Heat pipe and dedicated outside air system save the life cycle cost of window air-conditioning system.

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