Energy Saving Of Window Air Conditioning System Using Heat Pipes And Dedicated Outside – Air System

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Abstract- *A Dedicated outside air system is designed to satisfy 100% of the outside-air ventilation requirements established by ASHRAE using outside air and heat pipe technology. One of the main objectives of this Paper is to study the impact of Heat Pipe Based Heat Exchangers (HPHEX) on the performance of an air-conditioning system by using Dedicated outside Air System with separate ductwork. According to the fieldwork study, the air conditions established by the existing system are not within the comfort zone recommended by the ASHRAE. Therefore, enhancing the performance of the existing system by adding Heat Pipe based Heat Exchangers was studied. Heat pipes are highly efficient heat transfer devices, which use the continuous evaporation/condensation of a suitable working fluid for two-phase heat transport in a closed system. In experimental study we used two heat pipes in parallel banks with the evaporator coil separating the pipes evaporator ends and condenser ends. Then Fins are attached over the surface of the heat pipes to increase the heat transfer area of heat pipe. We comparatively studied the Energy cost & Life cycle cost of window air conditioning system (0.75 TR) with Electric heater and with combine heat pipe and dedicated outside air system. From experimental study we concluded that, the heat pipe heat exchanger system increases the COP of window air conditioning system, HPHEX reduced the energy consumption of system resulted in saving in electrical energy about 70.622 kW/year and Savings in life cycle cost of Vapour compression cycle system with heat pipe and dedicated outside air system is 1815.05 Rs/year.*

Keywords: *ASHRAE, DOAS, Energy Cost, Heat Pipe, HPHEX, Life cycle cost, Reheating Coil.*

I. INTRODUCTION

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. This is achieved by evaporation of the working fluid in the evaporator section and condensing in the condenser section and return of the condensate, as shown in Fig 1. The idea of heat pipes was presented first by Gaugler (1994) in General Motor Company in 1942. The first heat pipe was designed and manufactured by Grover (1966) in National Lab, Los Alamos, in the US in 1964[1].

The heat pipes for heat recovery equipment are aimed for recovering sensible heat and they are recommended for systems in which inlet and return air should not be mixed such as surgery rooms in hospitals and chemical and biological laboratories. The advantages of using heat pipes over conventional methods 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, together with simplicity of design and ease of manufacture [2].

The ventilation air is delivered by a separate dedicated outdoor air system (DOAS) designed to efficiently to remove the ventilation air latent load as well as 100% of the space latent loads. The terminal equipment, operating in parallel with the dedicated outside air system equipment, is required to remove only the sensible loads that remain after the dry ventilation air has been introduced into the conditioned space [3].

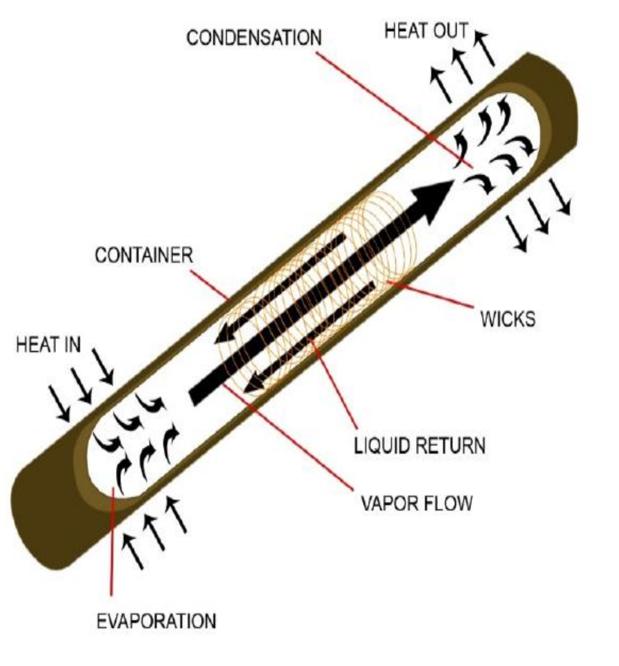

Fig. 1 A schematic of heat pipe operation [1]

The use of heat pipes as a 100% outside air conditioning design solution for new buildings conforming to ASHRAE Standards 62.1-20103 and 90.1-20104 and as a means to improve HVAC performance, Indoor Air Quality (IAQ), and energy efficiency in existing buildings. Meeting ASHRAE Standard 90.1-2010 requires the design of energy efficient HVAC systems, and it generally does not allow cooling and reheating of the same air stream. Many designers are now using this Dedicated outside Air Systems (DOAS) for buildings such as schools and offices as a cost-effective and energy efficient approach to meeting 62.1-2010 requirements [4].

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. Heat pipes can increase latent cooling by 25-50% depending upon the application [5].

M. Ahmadzadehtalatapeh studied the impact of Heat Pipe Based Heat Exchangers (HPHEX) on the performance of an air conditioning system in a library building. Heat Pipe Heat Exchanger System with four-row HPHEX, Six- row HPHEX, Eight- row HPHEX was examined in the system to determine the proper configuration. The results showed that the system equipped with the eight-row HPHEX could keep the library space approximately at 22.4 °C and 54.5% RH. In addition, it provides the supply duct air RH at 68.3%.The results showed that by the process of pre-cooling and reheating provided by the eight-row HPHEX, the total amount of 236.9 MWh energy could be saved in a year. This amount of saved energy made it possible to save a total amount of US$24,572 annually [6].

In this paper we had experimentally investigated the coefficient of Performance of window Air-Conditioner system with conventional electrical heater and with combine Heat Pipe and Dedicated outside air system at two different outside hot air temperature condition i.e. test 1 is performed at 320C and test 2 is performed at 280C. In this experiment we compare the Energy Consumption per year of Vapour compression cycle with heater module and Energy Consumption per year of Vapour compression cycle with heat pipe & Dedicated outside air system module. In this Experiment we also find the saving in Energy cost and life cycle cost per year of a window air conditioner system by replacing conventional electrical heater with heat pipe and dedicated outside air system.

II. EXPERIMENTAL SET UP

The Experimental set up of Heat Pipe Heat Exchanger System is shown in fig. 2. 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 .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 capacity of window air conditioner system is 0.75TR

The HPHEX system as shown in Fig. 2,3 consists of two parallel heat pipe having length 500mm and Diameter 16mm.One section of the heat pipe is located 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 working fluid used in heat pipe is water. The wick structure of heat pipe is made 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 R-134a.

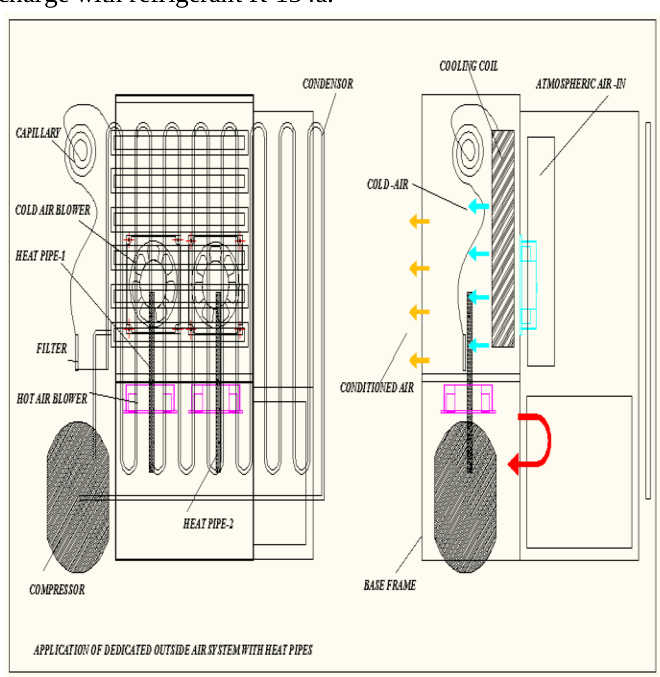

Fig. 2 Schematic diagram of Experimental Set Up

Fig .3 Front side Experimental set up of Air conditioning system.

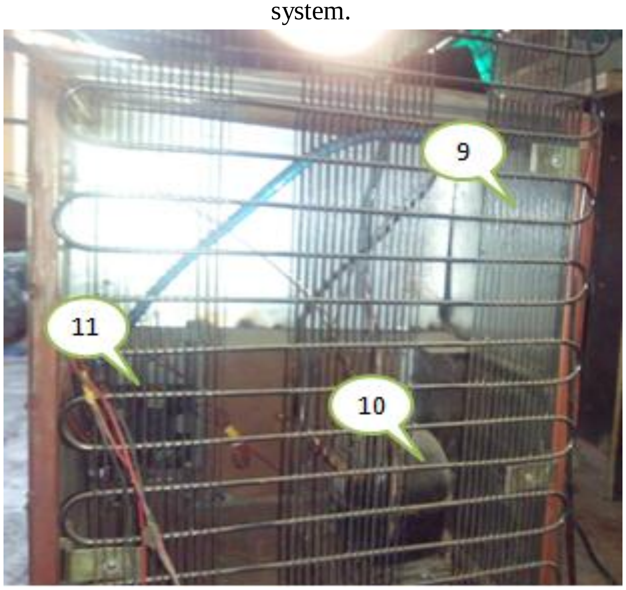

Fig .4 Back side Experimental set up of Air conditioning system.

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.

III. EXPERIMENTAL PROCEDURE

Test & Trial on window air conditioning system set up to determine temperature gradient, COP of system, Energy of Reheating, Energy cost and Life cycle cost under following mode:

(1) Mode 1: Test & trial on conventional Vapour compression model with electric heater module.

(2) Mode 2: Test & trial on conventional Vapour Compression model with combine Heat pipe & dedicated outside air system.

The above test and trial is performed at two different temperature conditions:

(1) Test 1: When outside hot air temperature is 320C

(2) Test 2: When outside hot air temperature is 280C

The Hot air, Cold Air temperature is measured by Digital Thermometer after the time interval of four minutes. Inlet air temperature are 32OC and 280C respectively for these conditions de-humidification purpose cooling coil temperature to be maintained at 150C,thus temperature of air leaving evaporator coil is 150C, which will be an uncomfortable temperature for human being hence the air is reheated by heater to 240C.

Procedure of trial:
1. Start compressor
2. Start cold air blower
3. Note cold air temperature after every four minutes.
4. Start Hot air blower
5. Note hot air temperature readings.

A. Mathematical relations

The coefficient of performance of Air-Conditioning system is given by,
Thermal input available at the evaporator vaporises the fluid and vaporised fluid travels through the inner core to condenser section. At the condenser region, the vaporised fluid condenses and latent heat is rejected through condensation [5].

$$COP = \frac{Qr\,(KW\ Refrigaration\ \ effect\ )}{Qi\ (KW\ input\ \ power\ )} \quad [1],[2] \qquad (1)$$

Where,

$$Qr = m\ X\ cp\ X\Delta T \qquad (2)$$

$$Qi = \frac{compressor\ \ power\ \ X\ time\ \ X\ 60}{1000} \qquad (3)$$

Energy Cost/year = Energy Consumption/year x rate per unit [4]

Life Cycle Cost = Running Cost + Maintenance cost [4]

IV.RESULT AND DISCUSSION

The test and trials performed on Window Air conditioning system with Electric Heater and with combine heat pipe and dedicated outside air system. The obtained results of Test 1are shown in Table I, II & results of Test 2 are shown in Table III & IV.

SR NO	TIME	ΔT	Net Compressor Power	mc_p ΔT	COP
01	4	6	104	72.288	2.896154
02	8	12	96	144.576	3.1375
03	12	15	111	180.72	2.261261
04	16	17	106	204.816	2.012736
05	20	17	102	204.816	1.673333

TABLE I
SUMMARY OF A.C SYSTEM WITH HEATER AT 32^0C

SR NO	TIME	ΔT	Net Compressor Power	mc_p ΔT	COP
01	4	5	103	60.24	2.436893
02	8	12	95	144.576	3.170526
03	12	15	91	180.72	2.758242
04	16	16	89	192.768	2.25618
05	20	17	85	204.816	2.008

TABLE II
SUMMARY OF A.C SYSTEM WITH DOAS AT 32^0C

SR NO	TIME	ΔT	Net Compressor Power	mc_p ΔT	COP
01	4	4	99	48.192	2.0282828
02	8	6	95	72.288	1.5852632
03	12	10	111	120.48	1.5075075
04	16	11	103	132.528	1.3402913
05	20	11	98	132.528	1.1269388

TABLE III
SUMMARY OF A.C SYSTEM WITH HEATER AT 28^0C

SR NO	TIME	ΔT	Net Compressor Power	mc_p ΔT	COP
01	4	4	98	48.192	2.04898
02	8	6	93	72.288	1.619355
03	12	9	91	108.432	1.654945
04	16	11	87	132.528	1.586782
05	20	12	85	144.576	1.417412

TABLE IV
SUMMARY OF A.C SYSTEM WITH DOAS AT 28^0C

From the result Table I, II, III and IV it is found that, the use of dedicated outside air system instead of electric heater reduces the net input power consumption of the window air conditioning system over the period of time as shown in fig 6 and 8. The COP comparison between the VCC with DOAS and VCC with Heater system at temperature 32OC and 280C are shown in Fig.5 and 7. From below graphs it is clear that the coefficient of performance of vapour compression cycle model with heat pipe & dedicated outside air system module is higher as compared to the vapour compression cycle module with electric heater.

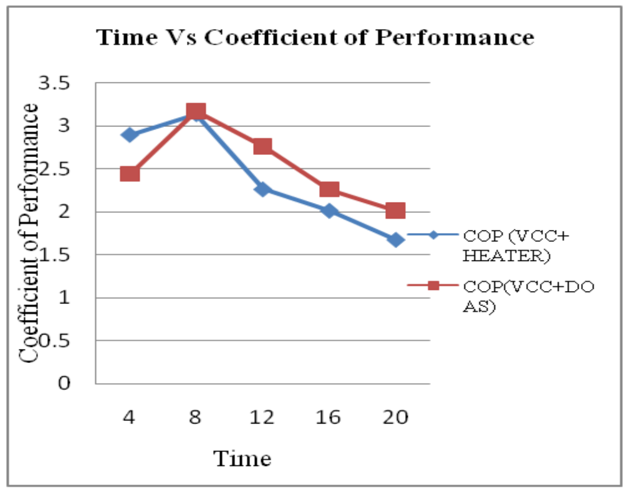

Fig 5- Time Vs coefficient of performance

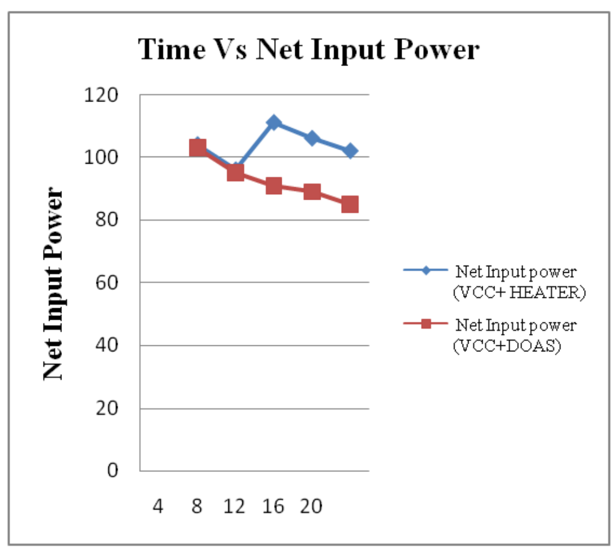

Fig 6- Time Vs net input power

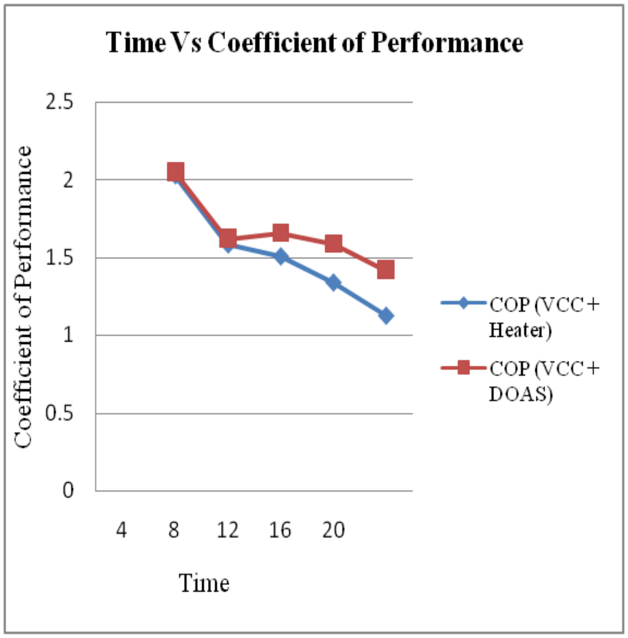

Fig 7- Time Vs coefficient of performance

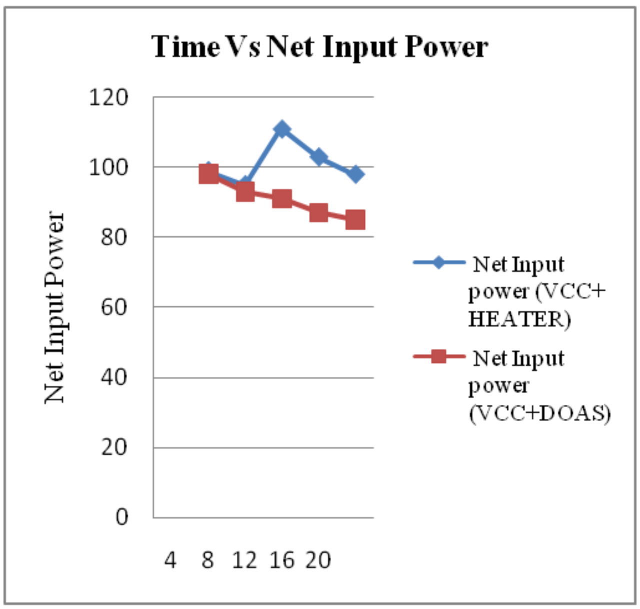

Fig 8- Time Vs net input power

The average energy consumption per hour is calculated considering both conditions of hot air temperature i.e. at 32OC and 280C

The Energy Consumption per year and Energy Cost of VCC system with heater and with heat pipe DOAS is calculated for one year when system running eighteen hours per day. Consider maximum load condition. The Cost of electricity per unit is eight rupees.

Total Energy Consumption per year of Vapour compression cycle with electric heater module is 663.552 kW

Total Energy Consumption per year of Vapour compression cycle with heat pipe module is 592.92 kW
Therefore,
The Energy cost of VCC system with electric heater = Energy Consumption per year x Electricity rate per unit
Energy Cost/year =663.552*8 = 5308.41Rs/year

The energy cost of VCC system with DOAS = Energy Consumption per year x Electricity rate per unit
Energy Cost/year =592.92*8 = 4743.36 Rs/year

Life cycle cost (VCC + HEATER system) = Running cost + Cost of heater replacement per year
= 5308.41+ 1250
= 6558.41 Rs/year
Life cycle cost (VCC + DOAS system) = Running cost + Cost of heat pipe replacement per year
= 4743.36 + 0
= 4743.36 Rs/year

SR. NO	SYSTEM	ENERGY COST/YEAR IN RUPEES	LIFE CYCLE COST/YEAR IN RUPEES
1	VCC +HEATER	5132.16	6382.16
2	VCC +DOAS	4354.56	4354.56

TABLE V
SUMMARY OF ENERGY COST AND LIFE CYCLE COST

Therefore, the saving in Energy cost per year by the application of DOAS System = Energy cost of (VCC +HEATER system) – Energy cost of (VCC +DOAS system)
= 5308.41 – 4743.36 = 565.05 Rs/year

The comparison between Energy Cost/year and Life cycle cost of VCC system with heater and VCC system with DOAS is calculated for one year graphically represented in Fig. 9.

The saving in Life Cycle Cost per year by application of DOAS System = Life cycle cost of (VCC +HEATER system) - Life cycle cost of (VCC +DOAS system)
= 6558.41 -4743.36 = 1815.05 Rs/year
Total life cycle cost saving considering the heat pipes and fan are to be replaced after five years is given by,

Total life cycle cost saving= 5* savings per year- cost of heat pipe reconditioning
= 5* 1815.05 – 1200 = 7875.25 /-

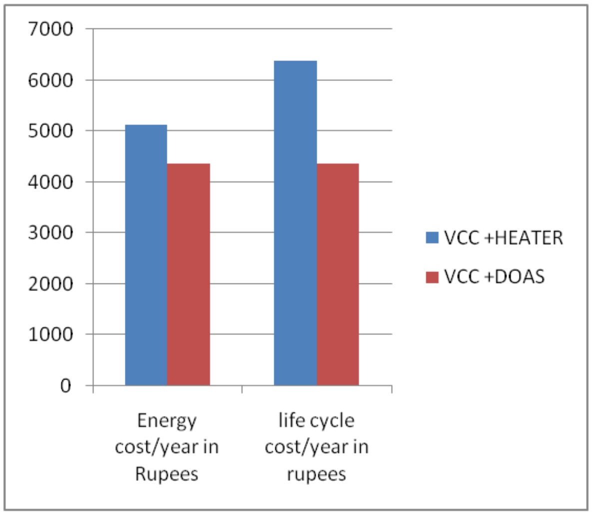

Fig.9. Comparison of Energy cost and life cycle cost

V. CONCLUSION

The experimental study of Heat pipe and DOAS Air Conditioning System lead to following conclusion:

1. Coefficient of performance of the window air conditioning system increases with application of the Heat Pipe & Dedicated outside air system.

2. Heat Pipe & Dedicated outside Air System decreases the net input power. Hence save the energy.

3. The Energy cost per year reduced because of replacement of Electric Heater with Heat Pipe & DOAS arrangement.

4. Use of Heat Pipe reduces the running cost and maintenance cost of Window Air-conditioning system as shown in Table III.

5. Hence Heat Pipe & Dedicated outside Air System Save the life Cycle Cost of Window Air-conditioning system.

Nomenclature :

Qr: Refrigeration effect in Kw.
Qi: Input Power in Kw.
m: Mass of air in Kg/s.
Cp: Specific heat of air in KJ/kg °K.
ΔT: Temperature change in °K.
COP: Coefficient of performance.
TEC: Thermoelectric cooler.
VCC: Vapor Compression Cycle.
SHR: Heat sensible Ratio.
HPHX: Heat pipe heat exchanger.
HP: Heat pipe.
PM: Peltier module.
TR: Tonne of Refrigeration

ACKNOWLEDGMENT

I would like to give my special thanks and appreciation to Mechanical department of G.S.M.C.O.E, Balewadi, Pune. I would also like to thank Prof. Vijay Bhatkar for valuable support and Prof. Mahesh Jagadale for kind cooperation during experimental work.

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