Pulsating Heat Pipe for Air Conditioning System: an Experimental Study

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Abstract— This Paper aim to develop a highly cost effective Air Conditioner with use of pulsating heat pipe instead of cooling coils. In conventional Air conditioner work on Vapour compression cycle with use of Compressor for increased pressure and temperature of working fluid, that is refrigerant. Compressor is very high power consuming device and needs great amount of electrical energy. Also compressor produces noise and requires maintenance. At present in India there is shortage of electrical power and there is large number of efforts are carried out to reduce power consumption. This paper is part of one such effort. Objective of this paper is to eliminate the use of high power consuming compressor and use a pulsating heat pipe instead of cooling coils. Eliminating use of compressor will definitely reduce the power consumption; and use of pulsating heat pipe will cause the flow of refrigerant without any external power.

Nomenclature:

D *Diameter (m)*

B_o *Bond Number*

Greek symbols

ρ Density (kg/m3)

σ Surface tension (N/m)

Subscripts

Cri *Critical Diameter*

L *Liquid*

V *vapour*

Key words: Experimental Study, Air Conditioning System

I. INTRODUCTION

Now a day there is great short stage of Electricity in India and Use of Air Conditioner is very essential in Indian climatic zone. The capital and running cost of these air conditioners is very high, and maximum people in India are below poverty level and will not able to afford it. This is the reason that people preferred Desert cooler instead of Air Conditioner. But this cooler will work effectively with very dry air and not in humid atmosphere. Also this cooler doesn't have control on humidity.Above mentioned problem faced by our society has motivated us to provide of solution in between Air conditioner and Desert cooler.

Pulsating or Looped type Heat Pipes proposed and patented by Akachi [1] in 1990s. This is the new member of wickless heat pipes. Their operation is based on the principle of oscillation for the working fluid and a phase change phenomena in acapillary tube. The diameter of the tube must be small enough such that liquid and vapour plugs exist. Due to its excellentfeatures, such as high thermal performance, rapid response to high heat load, simple design and low cost, PHP has beenconsidered as one of the promising technologies for electronic cooling, heat exchanger, cell cryopreservation, the spacecraft thermal control system, etc.

II. EXPERIMENTAL MODEL

The Experimental Model of Pulsating heat pipe air conditioning system was developed with fabrication of closed loop pulsating heat pipe (CLPHP). To design the CLPHP one must find the internal diameter of CLPHP.

A. Working Fluid

The working fluid used much has a boiling point around 25°C to deliver a comfort temperature Air. Pentane (C_5H_{12}) has boiling point temperature around 35°C at normal atmospheric pressure. Since we create a vacuum inside the PHP tube and having 50% filling ratio, it will boiled at 15-20°C temperature and will be able to deliver Comfort air at 25°C temperature.

About the tube design, the most important condition of PHP is the creation of the liquid slug. According to the literature review, Akachi [1] proposes that the appearance and movement of bubbles are affected by surface tension and buoyancy in the channel. Relation of surface tension and buoyancy could be explained by the dimensionless formula:

$$D_{cri} = 2 * \sqrt{\frac{\sigma}{g*(\rho_l - \rho_v)}} \quad (3.1)$$

$$B_o = D_{cri} * \sqrt{\frac{g*(\rho_l - \rho_v)}{\sigma}} \quad (3.2)$$

If D <D_{cri}, surface tension forces dominate and stable liquid plugs are formed. However, if D >D_{cri} , the surface tension is reduced and the working fluid will stratify by gravity and oscillations will cease.

For Pentane at 15°C

- Liquid Density (ρ_l) 629.4 Kg/m3
- Vapor Density (ρ_v) 3.228 Kg/m3
- Surface tension (□) 20 N/m

Hence value of critical diameter form equation (3.1) is 3.5mm. Hence form literature review shows that CLPHP gives better perform at 2 mm internal diameter tube for most of working fluid. Hence we select the diameter of CLPHP will be 2.1 mm.

B. Closed Loop Pulsating Heat Pipe (CLPHP)

Closed loop PHP is made of copper tube, with 2.1mm internal diameter and 3.0mm external diameter. The length of evaporators and condenser section is same; that is 450mm each,as show in figure (1.1) The PHP has 19 tunes; and has filling ration of 50%.

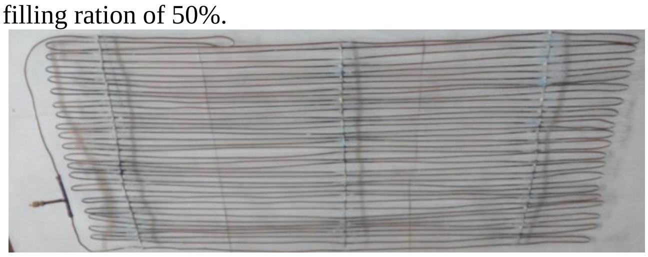

Fig. 1: Closed loop PHP

C. Cooling Fan

Two cooling fans are used to create an air current and forced the air over the evaporator section of CLPHP tubes; where air rejects heat to CLPHP tubes and its temperature gets reduces and CLPHP caries this heat to Condenser section. One cooling fan is used for cooling tower. This fan consumes very low power of 30 Watt and delivers 3 m3 /mint air and runs on 230Volt AC power. It is noise less and very efficient for given setup.

Fig. 2: Cooling Fans

D. Cooling Tower

The Cooling tower is the device which rejects heat into the high temperature reservoir. In A condenser section of CLPHP we used water as heat absorbing medium; which absorbs heat from CLPHP and its temperature gets increased. In order to main temperature of water lower than CLPHP we need to cool water with help of cooling tower.

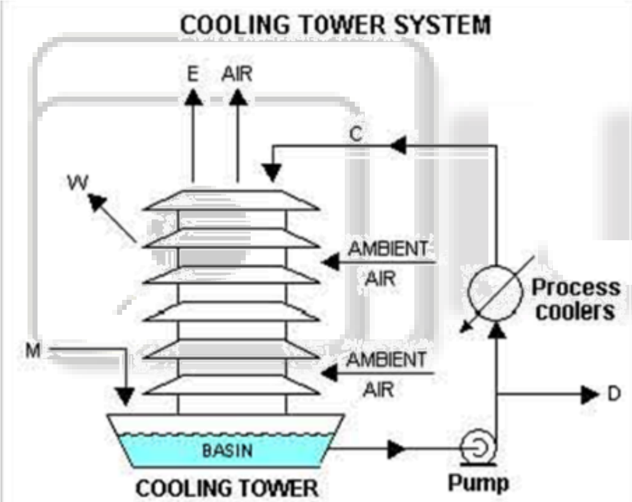

Fig. 3: Schematics Diagram of Cooling Tower

Fig. 4: Actual Cooling Tower

observations.This is possible with help of digital temperature Indicator and Thermocouple wires.

E. Thermocouples

Thermocouples used to observe the temperature of at different points. Hear we used Eleven K type Thermocouple wires to observe temperature at eleven different points.

Three thermocouples are fixed over the evaporator section of CLPHP and Three over the Condenser section. Two thermocouples are use to observe temperature of inlet and outlet Air to the Heat pipe air conditioners. Two thermocouples are fixed over the inlet and outlet water temperature to cooling tower. And one thermocouple will observe the average temperature of water in condenser section tank.

The overall arrangement of above mention devices and Thermocouples is shown below, in Figure 1.5.

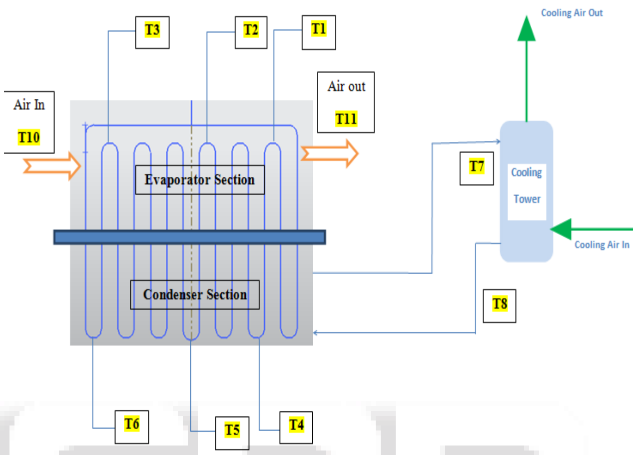

Fig. 5: Schematics of Heat Pipe Air-Conditioning Showing arrangement of all thermocouples

T1, T2, T3	Evaporator Temperature
T4, T5, T6	Condenser Temperature
T7	Water Inlet to Cooling tower
T8	Water Out to Condenser
T9	Avg. water temp. in Condenser
T10	Air Inlet Temperature
T11	Air Outlet Temperature

Table 1:

Fig. 6: Actual Experimental Setup for Heat Pipe Air Conditioning System

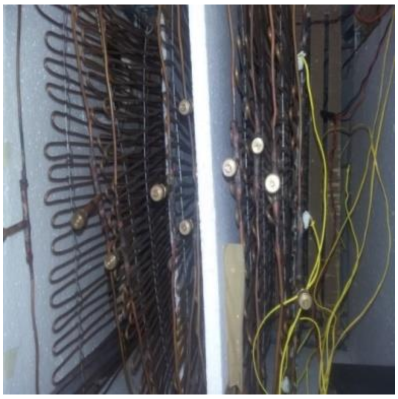

Fig. 6: Top view of Experimental Setup

F. Thermocol

Thermocol is an insulating material used to avoid the loos of heat and avoid the contact of Inside air with outside walls. Also those are used as Baffles to create a restricted path to flow of air and increases contact time between air and cooling coils.

III. EXPERIMENTAL PROCEDURE

1) Evacuate the PHP with Vacuum pump.
2) Filled PHP with Woking Fluid.
3) Filled the condenser section with water.
4) Start the Cooling fans of Heat Pipe Air Conditioner, Cooling tower, Submersible water pump.
5) Observe the Readings on Digital temperature Indicator.

IV. RESULT AND DISCUSSION

In this chapter we will discuss the nature of experimental values; and compares the experimental results of different operating conditions. The experiment was conducted in three different operating conditions; that are Indore, Window and Outdoor.

A. Indore Operating Conditions

During this operating condition Air conditioner is located inside the closed room; and there is no direct change in temperature of inlet air with time.

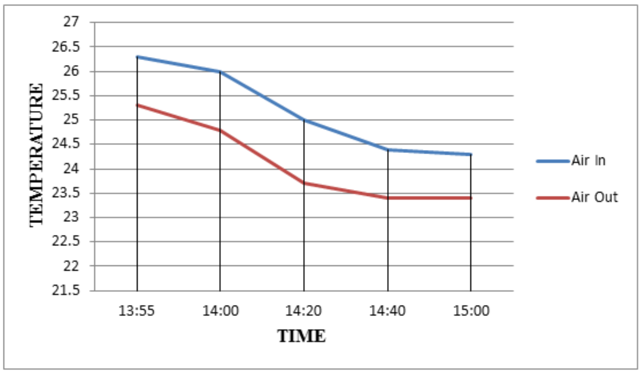

Fig. 7: Change in Temperature of Inlet and Outlet air with time for Indoor operating condition

Graph (5.1) shows the change in temperature of air with time; when operating air conditioner in indoor operating condition. Here in this graph, the characteristic clearly show that the temperature of inlet and outlet continuity drops initially. Then after some time spans the cure becomes straiten; and there is very small change in temperature difference between inlet and outlet air.

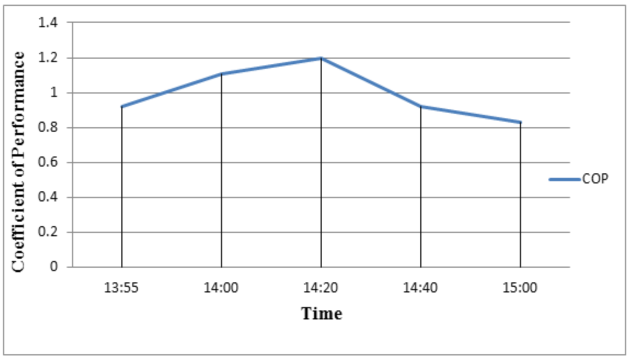

Fig. 8: Change in COP with time for Indoor operating condition

The graph (5.2) shows the change in COP with time for Indore operating condition. This graph shows that value of COP first Increases reaches some high value and then again decreases to previous value. This is because at beginning the temperature of evaporator coils is more and also inlet air temperature. Since the system is working and condenser cools the tubes continually temperature of evaporator tubes drops suddenly and there is increasing in temperature difference between Inlet and outlet air. Hence increase the COP. But after certain interval of time inlet air temperature also drop due to cooling of room and hence there is decrees in temperate difference and so COP.

B. Window Operating Condition

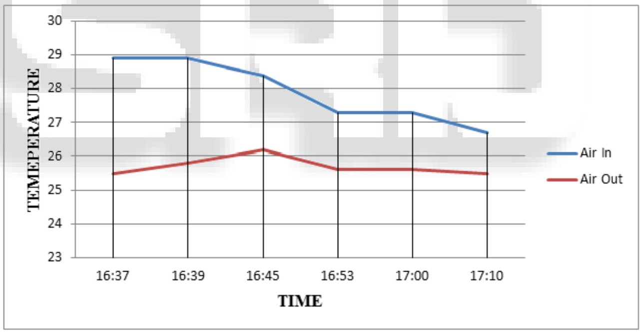

Fig. 9: Change in temperature of Inlet and Outlet air with time for Window operating condition

In this operating condition, air conditioner is located into the window; but not outside the room. Hence there is slight change is temperature of inlet air with time. Graph (4.3) shows the change in temperature of air with time. The inlet air temperature is continuously keep changing but air conditioning system is able to deliver the comfort air at temperature of about 25 °C.

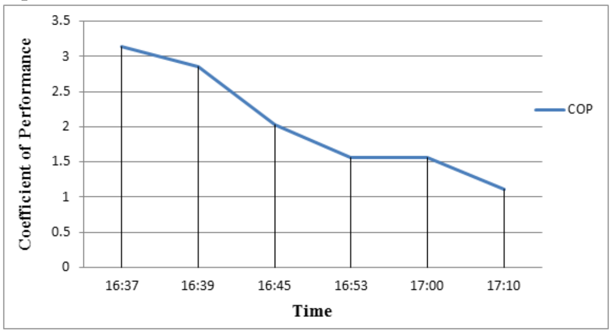

Fig. 10: Change in COP with Time for Window Operating Condition

The graph (5.4) shows the change in COP with time for Window operating condition. The nature of curve shows that, there are continuous decrees in COP of Air Conditioning system. This is due to decrees temperature difference between Air in and Air out.

C. Outdoor Operating Condition

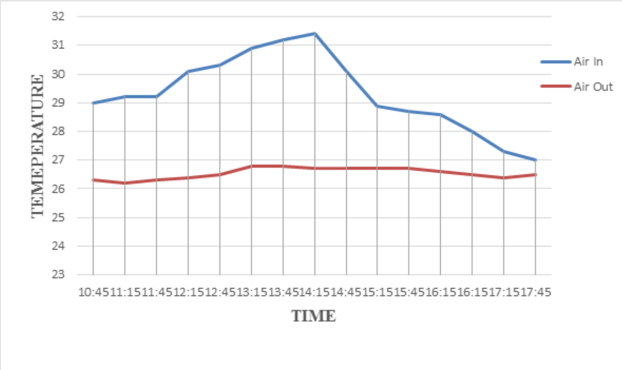

Fig. 11: Change in temperature of Inlet and Outlet air with time for Outdoor operating condition

In outdoor operating condition the whole system is located outside the room and only inlet air is supplied into room. The graph (5.5) shows the change in temperature of inlet and outlet air with time. For sack of more understanding hear we shown the full day reading for outdoor operating condition. The nature of this curve shows that with increasing temperature of inlet air there is slight increasing temperature of outlet air and system efficiently delivers the comfort air at temperature of around 26 °C. The inlet and outlet air does not come to equilibrium. The Curve shows temperature difference first increases due to increasing temperature of outside air; reaches maximum and then decrees again.

Fig. 12: Change in COP with time for Outdoor operating condition

Graph (5.6) shows the change in COP with time. The typical nature of cop shows that COP increases to maximum because in midday time there is maximum temperature difference. Hence the COP increases to maximum. After the midday time again temperature of inlet air stars falling and hence there is decreasing in cooling effect and hence COP.

V. Conclusion

In the present work, the experimental analyses are carried out on a nineteen loop PHP with pentane as working fluid.
From these experimental analyses the following conclusions are drawn:

1) It creates cooling effect around 5 °C and effectively delivers cold air at comfort air temperature of 25°C.
2) The indoor operating conditions give more satisfying results than window and outdoor condition.
3) The power consumption is about 109 Watts and this power consumption is lower than one ceiling fan.

The quantity of water required for producing this much of cooling effect is about only 2 to 3 liters per day. Hence there is huge saving of water and Electricity.

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