Evaluating Possible Configuration Of Incorporating Earth Heat Pipe Heat Exchanger And Peltier Module Into Air Conditioning System

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Abstract- *In the present age with depleting sources of energy there is always a target to get the best energy ratios so that there will be minimum electric power consumption in operation of the air conditioning units.*

Individually the ideas like Earth heat exchanger cooling, thermoelectric cooling did not stand good but by combination of two or more concepts in a collaborative manner stands a possibility to develop an energy efficient method of air conditioning. Based on the above concept Experimental set-up is formulated. The Experimental set-up is tested with different combinations of VCC, heat pipe heat exchanger and thermoelectric module for various performance parameters such as COP, temperature drop, compressor power, Refrigerating effect, Energy saving etc. The COP of the conventional 0.75 TR window type air conditioner is found to be increased from 1.8531to 2.8675 and energy saving is observed to be 13.83% with the combination of conventional 0.75 TR window type air conditioner with heat pipe heat exchanger and thermoelectric module.

Keywords: *COP, Energy saving, Heat Pipe, VCC, Peltier module, Temperature Gradient, VCC*

I. INTRODUCTION

In general most of the people feel comfortable in the temperature range between 22°C to 25°C and relative humidity within 30 to 50% such a condition can be easily achieved through the use of air conditioning equipment. Hence, there is significant use of electrical energy in this area. Different methods are used for reducing these energy demands [1] e.g. Earth-air heat exchanger, Thermoelectric cooling.

The temperature of earth at about 2 to 3m is nearly constant throughout the year. This undisturbed temperature remains higher than the outside temperature in winter and lower than the outside temperature in summer. When the atmospheric air is passed through the buried pipes, the air is cooled in summer and heated in winter [2].

An Earth-air heat exchanger is an underground heat exchanger that can capture heat from and/or dissipate heat to the ground. They use the Earth's near constant subterranean temperature to warm or cool air or other fluids for residential, agricultural or industrial use [3]. Earth tubes are often a viable and economical alternative or supplement to conventional central heating or air conditioning systems since there are no compressors, chemicals or burners and only blowers are required to move the air. These are used for either partial or full cooling and/or heating of facility ventilation air.

An Earth heat exchanger is a heat pipe heat exchanger in which air is used as medium of heat transfer. Compared with other heat recovery equipments, heat pipe is a passive heat transfer device with high effective thermal conductivity. Heat pipe has no mechanical components, high life and works only depending upon temperature differences [4].

A heat pipe consists of a sealed container, a wick structure, a small amount of working fluid that is just sufficient to saturate the wick. The length of the heat pipe is divided into three sections viz. Evaporator section, adiabatic section and condenser section. Figure 1 shows the main regions of a heat pipe [5].

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].

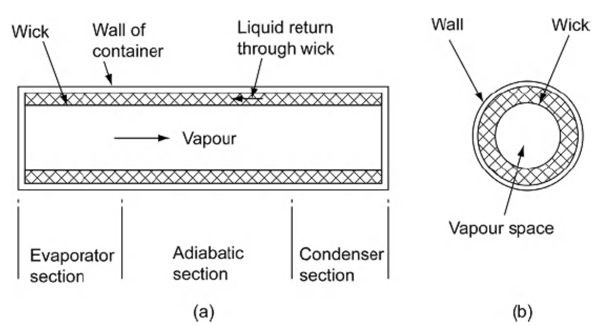

Fig 1. The main region of heat pipe [5]

Thermoelectric cooling is another supplementary cooling method in which thermoelectric cooler (TEC) cold side sink and hot side larger sink of the cooling system as shown in figure 2. Thus at the cold surface heat is absorbed and heat is rejected at the hot surface similar to a heat pump. The circulating fan on the hot side circulates atmospheric air which absorbs some of heat collected [6].

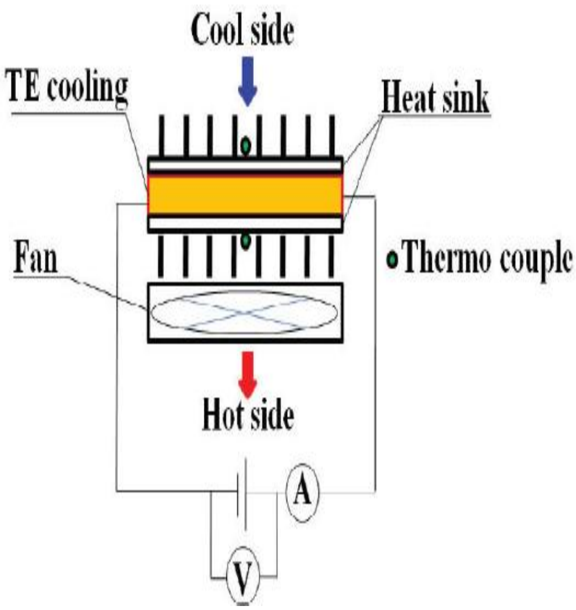

Fig 2. Thermoelectric cooler (TEC) [6].

The potential of heat pipe heat exchanger for space cooling is well accepted in hotter countries. Yat H. Yau [7] experimentally investigated that, how the sensible heat ratio (SHR) of HPHX was influenced by each of three key parameters of the inlet air state, namely, dry-bulb temperature, and relative humidity and air velocity. On the basis of this study, it is recommended that tropical HVAC systems should be installed with heat pipe heat exchangers for dehumidification enhancement and saving the energy. The experimental results demonstrated that for all cases examined, the overall SHR of the HVAC system was reduced from the maximum of 0.688 to the minimum of 0.188 by the HPHX as inlet DBT to the HPHX evaporator increased. Yat H. Yau [8] studied experimentally, a heat pipe heat exchanger to dehumidification enhancement in tropical HVAC systems a baseline performance characteristics study, the author had established the baseline performance characteristics of the eight-row wickless heat pipe heat exchanger (HPHX) for a vertical configuration under a range of conditions appropriate for a tropical climate. The same basic experimental set-up was to be used in the present research with the HPHX tilted 30º C. The results suggested that the possibly adverse influence of condensate forming on the fins of the HPHX was negligible, and therefore the HPHX in a typically-used vertical configuration could perform equally as well as it would if the HPHX was installed in an inclined position.

Christian J.L. Hermes et al [10] tested a thermoelectric, a Stirling and two vapor compression refrigeration systems at two different ambient temperatures (21 and 32 °C) using a climatized chamber. They conclude that the Stirling and the reciprocating vapor compression refrigeration systems presented similar overall thermodynamic efficiencies (~14%), followed by the linear vapor compression system (~8%) and then by the thermoelectric cooler (~1%). Mayank Awasthi et al [11] studied the design and developed a working thermoelectric refrigerator interior cooling volume of 5L that utilizes the Peltier effect to refrigerate and maintain a selected temperature from 5°C to 25°C. They designed this system to cool this volume to temperature within a time period of 6 hrs and provide retention of at least next half an hour. With the help of design module the achieved retention time was 52 min. The retention time can be increased by using additional heater on heat sink up to 57.

From above study, it is clear that most of the work is carried out by using only VCC with Thermoelectric system and VCC with Earth heat exchanger. Keeping in this mind, individually these ideas do not stand good but by combination of two or more concepts in a collaborative manner stands a possibility to develop an energy efficient method of air conditioning. Thus there is beneficial to use the conventional vapor compression cycle in conjunction to thermoelectric cooling and earth heat exchanger technique to reduce the power consumption of the air conditioner and thereby increase the COP of system by refrigeration as the heat load is reduced by non-conventional earth heat exchanger cooler.

This paper experimentally investigates thermal performance of the hybrid air conditioner in four different modes by integrating active and passive cooling system, i.e. combination of window air conditioner, heat pipe and thermoelectric cooler. An attempt has been made to improve the COP of combine system.

I. EXPERIMENTAL SETUP

The set up of hybrid air conditioner is as shown in figure 3 and 4. It consists of two heat pipes of 275mm length and 12mm diameter. One end of heat pipe is buried under the soil chamber in water is percolated to have an effect similar to that under the ground at a depth of 2 to 3m.The other end of heat pipe with is located in air flow stream created by a single phase fixed speed motorized blower of 6 watt having maximum speed of 2350 rpm and maximum flow rate of 0.08 m^3/s. The refrigeration unit is charge with refrigerant R-134a. The heat pipe is provided with radial fins made up of aluminium. It also consists of peltier cooler SP-262-1.0-2.5

(Series) of 144 watt. Spiral fins over a cylinder are provided in order to increase the heat transfer area. The capacity of air conditioner is of 0.75 TR.

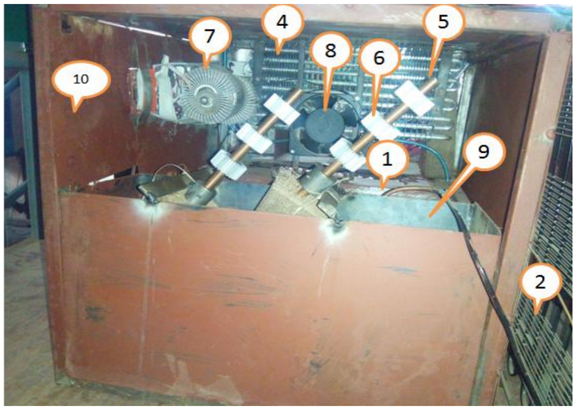

Fig.3. Back side of Hybrid air conditioner

Fig.4. Front side of Hybrid air conditioner

1-Compressor, 2-Thermostat, 3-Accumlator, 4-Evaporator coils, 5-Heat pipe, 6-Radial fins, 7-Peltier cooler with a cylinder and spiral fins, 8-Air blower, 9-Soil chamber, 10-body.

II. MODES OF HYBRID AC AND TEST PROCEDURE

Test & Trial on hybrid air conditioner determine temperature gradient, cooling ability (tonnage) and COP of system, under given modes

(1) Mode-I: Vapor Compression Air Conditioning unit and derive performance characteristics

(2) Mode-II: Vapor Compression Air Conditioning unit with peltier module unit and derive performance characteristics

(3) Mode-III: Vapor Compression Air Conditioning unit with heat pipe unit and derive performance characteristics

(4) Mode-IV: Vapor Compression Air Conditioning unit with peltier module, heat pipe and derive performance characteristics

The initial (ambient) air, final Air (air over evaporator coil) temperature is measured by Digital Thermometer after the time interval of three minutes. The discharge of blower is regulated so that mass of air per hour is kept constant to a value of 10.4 kg/hr.

Procedure of trial:

1. Start compressor
2. For

Mode-I: Peltier module is kept off as well as water percolation in soil chamber is not supplied.

Mode-II: Peltier module is switched on and water percolation in soil chamber is not supplied.

Mode-III: Peltier module is kept off and water percolation in soil chamber is supplied.

Mode-IV: Peltier module is switched on and water percolation in soil chamber is supplied.

3. Note down the temperature and compressor power and peltier module power.
4. Switch off electrical supply to the compressor.

A. Mathematical relations.

The coefficient of performance of Air-Conditioning system is given by,

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

Where,

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

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

III. RESULT AND DISCUSSION

After test and trial made during each mode following results are tabulated

TABLE I
SUMMERY OF MODE-I

SR NO	TIME	ΔT	Net Compressor Power	mc_p ΔT	COP
01	3	1	17.64	10.4675	0.593396
02	6	4	34.56	41.87	1.211516
03	9	8	51.3	83.74	1.632359
04	12	12	67.68	125.61	1.85594
05	15	15	84.6	157.0125	1.8559

SR NO	TIME	ΔT	Net Input Power	$mc_p\,\Delta T$	COP
01	3	2	20.16	20.935	1.038442
02	6	6	38.16	62.805	1.645883
03	9	10	52.92	104.675	1.977986
04	12	13	66.24	136.0775	2.05431
05	15	18	79.2	188.415	2.378977

TABLE II
SUMMARY OF MODE-II

SR NO	TIME	ΔT	Net Input Power	$mc_p\,\Delta T$	COP
01	3	2	16.38	20.904	1.127629
02	6	7	32.04	73.164	2.283521
03	9	9	44.82	94.068	2.098795
04	12	12	59.04	125.429	2.12439
05	15	16	72	167.232	2.322667

TABLE III
SUMMARY OF MODE-III

SR NO	TIME	ΔT	Net Input Power	$mc_p\,\Delta T$	COP
01	3	2	16.02	20.935	1.127508
02	6	7	31.32	73.164	2.095189
03	9	12	46.44	125.424	2.609738
04	12	15	59.76	156.78	2.623494
05	15	20	72.9	209.04	2.86749

TABLE IV
SUMMARY OF MODE-IV

From above result various performance parameters such as COP, temperature drop, energy saving, Refrigerating effect, Input energy are plotted against time which are represented as follows.

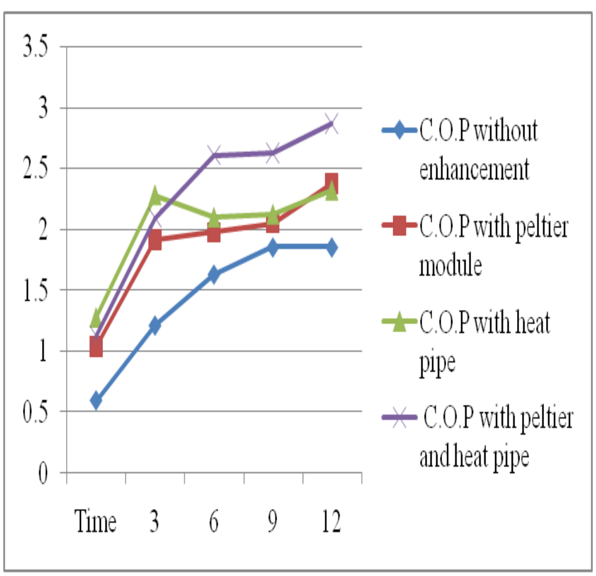

Fig.5. C.O.P Vs Time (min)

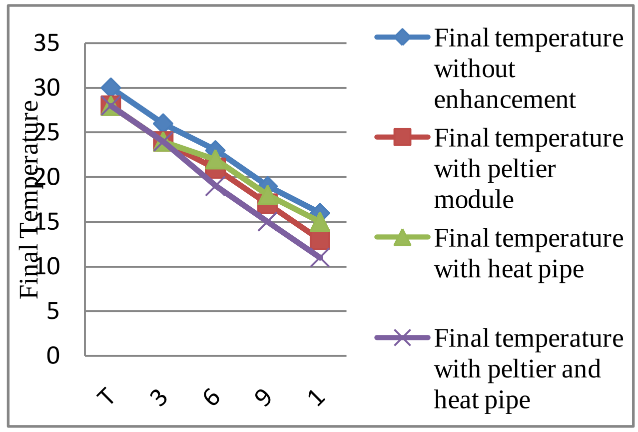

Fig.6. Final Temperature Vs Time (min)

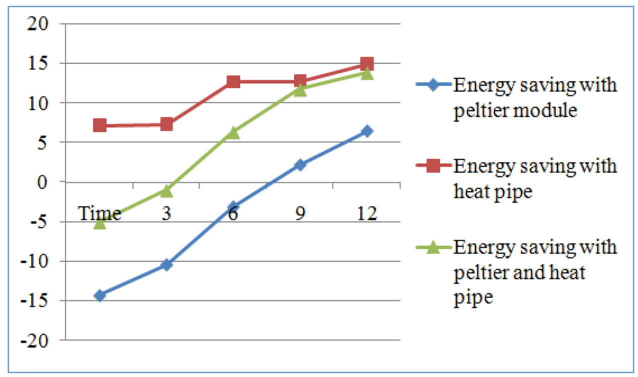

Fig.7. Energy saving Vs Time (min)

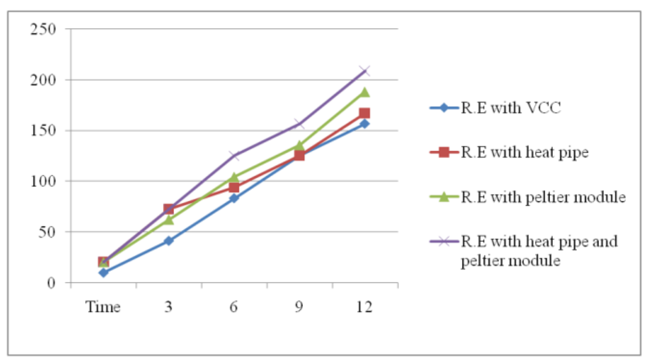

Fig.8. Refrigerating effect Vs Time (min)

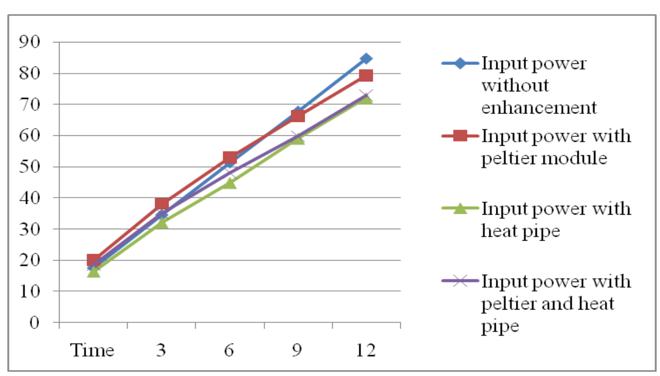

Fig.9. Input power Vs Time (min)

The first mode of operation in which air conditioner is operated only is considered as the base case. The performances of other modes are compared with the base case, which is purely a active cooling system without enhancement. (Since in first case it is not coupled with heat pipe or peltier cooler)

Fig 5 shows the variation of COP with time for different modes. COP of mode-IV (VCC+PM+HP) is maximum and thus most effective of the three combinations hence it is recommended that all three combinations of the hybrid system be used for best results. Comparison of the COP of mode-II (VCC+PM) & III (VCC+HP) represents that mode-II (VCC +PM) show better COP as compared to the mode-III (VCC+HP) over delayed duty cycle i.e., from 12 to 15min, hence will be recommended if the temperature cycling is to done over a range above 12minutes time. Comparison of the COP of mode-II (VCC+PM) & III (VCC+HP) shows that mode-III (VCC+HP) shows better COP as compared to the mode-II (VCC+PM) over short duty cycle i.e., from 0 to 12min, hence will be recommended if the temperature cycling is to done over a range below 12minutes time. The maximum COP of module-I, II, III, IV are 1.8531, 2.3745, 2.3227, 2.8675 respectively.

From fig.6 it is clear that Temperature reduction is maximum with mode-IV. When compared with the base case i.e. Mode-I, values of maximum temperature percentage reductions are 18.75, 6.25 and 31.25 for Mode-II, III, and IV respectively.

The maximum energy saving is also one of the important parameter that should also to be considered. Fig.7 shows the variation of energy saving with time when compared with the base case. The maximum energy saving is observed to be 14.89% with mode-III since heat pipe is a passive cooling enhancement. The values with mode-IV and II are 13.83% and 6.38% when compared with the base case respectively.

Fig.8 shows the variation of refrigerating effect with time. Figure shows that VCC with heat pipe and peltier module shows very promising results. For the same time period the refrigerating effect with the mode-IV will increase by 33.13%.

Fig.9 shows variation of input power with time. From the figure it is very clear that input power required over a period of time reduces considerably with various combinations as compared with the base case.

IV. CONCLUSIONS

The experimental study of air conditioner working on VCC with combination of heat pipe and peltier module lead to following conclusion:

1. The maximum COP with mode-IV will rise to 2.8675 as compared to the base case with 1.8531.
2. The Maximum percentage temperature reduction with mode-IV is 18.75% compared to the base case with total energy saving slightly (negligibly) less than mode-III.
3. The maximum energy saving is observed to be 14.89% with mode-III since heat pipe is a passive cooling enhancement.
4. The refrigerating effect with made-IV will increase by 33.13% for the same time period

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

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