Performance Evaluation of Porous Clay-Tube Air Cooler in Comparison with Conventional Evaporative Air Cooling System

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Abstract - **Now a day due to energy crisis and increasing demand along with its harmful effect to environment, there is urgent need of energy saving in air cooling systems. Although, evaporative cooling is well known technique from long time providing best results with applicability in number of areas such as, in residential, commercial, agricultural, and institutional buildings to industrial applications. However, Direct evaporation systems lead to increased humidity causing a number of ailments like whereas indirect systems suffer from loss in efficiency. Keeping these points in view, this paper describes the development of a test setup and performance evaluation of a clay tube air cooler. This system may also be used as an enthalpy exchanger depending upon the characteristics of prevailing air. Water in the tank is made to drip at a controlled rate into the porous clay pipes that allow capillary action. A thin layer of water formed on the surface of clay pipes is used to exchange sensible and latent heat with the current of outdoor air. The water circulating pump which is a primary component of any evaporating cooling system is absolutely not required in this system. This system is highly efficient can save up to 30-40% of high-grade electrical energy and 50% of the water in comparison to conventional evaporative air cooler. This paper covers performance evaluation of the system in terms three response parameters i.e. Dry bulb temperature (DBT), Wet bulb temperature (WBT) and Relative Humidity (RH).**

keywords - **Evaporative system, clay pipes, DBT, WBT, RH.**

I. INTRODUCTION

Numerous environmental and economic impact such as, depletion of the ozone layer, Green house effect, increasing cost of energy, and the other economic aspects have motivated research fraternity to develop alternative cooling technologies. In various regions of the India and other countries, summers are very hot with low humidity, which leads to physiological hazards in human body and other discomforts. Direct evaporative cooling system is a kind of extensively used cooling technique and in use since last decades for comfort in domestic and official purpose. The popularity of evaporative coolers in the market is due to its low cost, low maintenance and low electricity consumption in comparison to costly air conditioners.

There are number of advantages of direct evaporative cooling system such as, high thermal power per unit area, less consumption of energy, less impact on ozone layer depletion and green house effect because of zero ozone depletion potential and zero global warming potential. However, apart from these advantages there are numbers of drawbacks for the use of evaporative cooling such as, limited cooling as per comfort requirements, limited quantity of sensible heat removed, moisture added to the air during cooling process which increases humidity in the air up to unacceptable levels. Thus, this system is not adoptable at all environmental conditions. Evaporative cooling is therefore satisfactory only in areas where Dry bulb temperature (DBT) exceeds 32º and wet bulb temperature (WBT) is below 21º.

The present study is focussed on use of Semi Indirect Evaporative Cooler (SIEC) in which water is filled in porous clay containers that passes through the porous wall and wets the surface. Evaporation action takes place because of air sweeping across the container surface resulting in cooling of the surface and air. The main feature of this system is that the cooled air does not carry water droplets with it thus, reducing chances of humidity. The temperature of the air is further reduced sensibly due to its contact with the cooled pipe surface. A number of studies have been done stating the features of SIEC **[1-8]**.

The application of environmentally friendly cooling technologies has raised attention of research fraternity and consumers due to the large amount of electrical energy consumed by traditional air conditioning systems **[9]**. The air-conditioning units can be applied in any climate, however, it is expensive and it is not eco-friendly units. The higher working and living standards correlated with the reduced prices of air-conditioning systems caused significant increase in demand for air-conditioning in buildings. The current electricity consumption is around four times greater than the 1996 value **[10]**. Thus, the only solution left with us as an alternative to the traditional air conditioning systems is indirect evaporative cooling system.

Indirect evaporative air coolers (IECs) has proven to be an effective solution of new eco- friendly air-conditioning units **[11-14]**. Unlike direct evaporative air coolers (DECs), where water is evaporated directly into the air stream, such devices operate on the basis of evaporation of the water film which occurs on one side of the heat exchanger's plate. The usage of IECs in practice has been investigated by many researchers and observed it as a comfort conditioning system at minimal costs. The studies for evaporative cooling system compared the performance with traditional cooling system and found considerable drop in the temperature of water in a porous ceramic pot to be 10.4–15ºC below the ambient temperature **[15-16]**.

A study observed a temperature drop of 10–13ºC in a box shaped evaporative cooled chamber (ECC) constructed of zinc whose outer surface was covered by continuously wetted charcoal layers **[17]**. A number of studies measured the transient response of an ECC and observed the changes in ambient relative humidity (RH) and temperature during dry and wet seasons. The box shaped ECC had two clay walls with continuously wetted coconut fibre filling the gap between the walls. On average, the temperature inside the ECC was 1–8.2 ºC and 3–12ºC lower than the ambient value during the wet and dry seasons, respectively. The ECC also increased the shelf lives of tomatoes and pumpkins by factors of 2.9 and 5 above their open-air storage values **[18-25].**

In an experimental investigation of porous ceramic evaporators for building cooling, A study measured dry bulb temperature (DBT) drops of 6–8ºC with a 30% increase in the RH of the inlet air. The cooling effect was enhanced by a high porosity of the evaporator, increased water supply pressure, and a single row of evaporators in the air duct **[26]**. In a study it was investigated that hollow fibre membrane contactors, which have a large mass transfer area per unit volume, with water and air flowing inside and outside the micro porous tubes, respectively, also have a good potential for space air conditioning **[27]**. A study presented a theoretical model in which wet honeycomb paper is used as the packing material through which the air stream to be cooled and humidified flows in a cross-flow fashion **[28]**. Dynamic models were developed for predicting the thermal performance of roof ponds of special designs for cooling buildings in hot and arid climates **[29-30]**.

A study recently proposed a more elegant model, which describes the cooling of a high-moisture cylindrically shaped food via convection and evaporation at its surface. This model was based on numerical calculations with the heat diffusion equation inside the food body, which showed that except for a short initial time, the average temperature remained in a fixed location. The study showed good agreement between the theoretical predictions and experimental data indicate the usefulness of the models for the rational design of evaporative cooled chambers and hollow fibre membrane or porous ceramic units for room air conditioning **[31]**.

II. Problem Definition

After study of all the literature related to cooling techniques and analysis of existing cooling techniques, it is found that the installation and running cost of an air conditioner is too high also it emits green house gases which are harmful to environment. In other side the conventional evaporative air cooler is less expensive than air conditioner but it has some limitations in cooling. The use of evaporative cooler makes high humidification with decrease in DBT in closed areas creating stickiness on skin and un-comfort conditions for human being. present study is focused on improving performance of evaporative cooling system.

The literature-reviewed show that it is needed to optimize the process parameters, which ultimately affect over the performance of the air cooling system. For accomplishment of the present work, after fabrication of the proposed air-cooling system having clay tube will be operated with different day timings and their performance will be compared with conventional evaporative air coolers at the same timings. Further, study will be accomplished by identifying different process parameters and their comparison with conventional air-cooling system to measure the performance.

III. MATERIAL AND METHODS

Present study involves the use of indirect evaporative cooling system, as it is most widely adopted technique for producing cooling effect with energy and cost saving. Thus, for accomplishment of the present work, the air cooler setup made of clay pipe is fabricated which is comprised of Sheet metal structure for the cooler, cylindrical clay pipes, fan (D.C.), water collecting tank and cabinet. The clay tubes used for present work is as shown in figure 1. Finally, the clay tube were fixed in the cooler at specific locations. The clay tubes were fitted vertically inside the structure by the help of circular holes and filled with water. The appropriate gap was maintained between the tubes for proper circulation of air surrounding the tubes as shown in Figure 2.

In the present experimental set up the thin layer of water formed on the surface of clay tubes is used to exchange sensible and latent heat with the circulating air. In this arrangement, the water once filled in the tubes is consumed in 7-8 hours or can say for a full working day. Therefore, there is no requirement of water circulating pump, which is a primary component of any conventional evaporative air cooler. The organization of the elements in air cooler is as shown in figure 3 as placed in room.

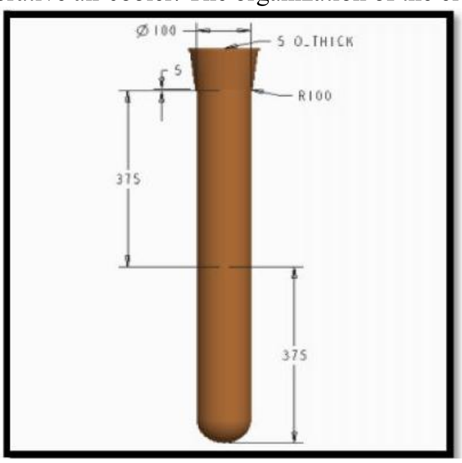

Fig.1 Cylindrical Clay Tube

Fig.2 Vertical Arrangement of Clay Tubes

Fig. 3 Actual View of Clay tube Air cooler placed in room

IV. TESTING METHODOLOGY AND RESULTS

For performance measurement, the clay tube cooler and conventional evaporative cooler were kept in two different rooms of same dimensions. The size of both rooms was 15*10*10 (In feets). The tests were carried out at different times in a day for getting the average values of parameters for evaluating the cooler performance at constant speeds of both coolers. The Cooler was switched on after measuring the performance parameters of outdoor air. The performance parameters chosen were DBT, WBT and Relative humidity (RH) which were measured with the help of sling psychrometer and hygrometer. After achieving the steady state condition, the same values were also measured for indoor air.

For further test measurements, both rooms were kept closed for next 70 minutes and readings were taken after that. The readings were taken at four different timings in a day starting from 11.30 am with interval of 70 minutes i.e. at 11.30 am, 12.40 pm, 1.50 pm, 3.00 pm. These timings were chosen because this is the main time in a day when there are more fluctuations in the temperatures and humidity in the environment, thus will provide accurate results for analysis purpose.

Firstly, two raw reading were taken at specified timings for DBT and WBT and their average will be considered for further analysis purpose for both conventional and clay tube coolers. At the same timings, RH will be calculated either using Hygrometer or directly using psychromteric chart with help of values of DBT and WBT and will be stored in respective table. Furthermore, the difference between DBT and WBT will be counted at each time, which will be helpful in further analysis purpose. Finally, the values of DBT, WBT and RH will be compared with comfort conditioning values to check significance of the results.

The readings are as shown in Table 1,2,3 and 4 respectively for DBT and WBT for conventional and clay tube coolers.

Table 1 DBT Raw Reading for Conventional Cooler

Time (Min.)	R1 (ºC)	R2 (ºC)	Average (ºC)
0	33	32	33
70	30	30	29
140	23	24	24
210	21	20	21

Table 2 DBT Raw Reading for Clay Tube Cooler

Time (Min.)	R1 (ºC)	R2 (ºC)	Average (ºC)
0	33	34	34
70	30	29	30
140	27	28	28
210	27	27	27

Table 3 WBT Raw Reading for Conventional Cooler

Time (Min.)	R1 (ºC)	R2 (ºC)	Average (ºC)
0	25	23	24
70	20	19	20
140	19	18	19
210	17	18	18

Table 4 WBT Raw Reading for Clay Tube Cooler

Time (Min.)	R1 (ºC)	R2 (ºC)	Average (ºC)
0	23	24	24
70	23	23	23
140	21	20	21
210	19	20	20

This section deals with comparison of process parameters (DBT, WBT, RH) for conventional and clay tube coolers. After taking average values of DBT and WBT from Table 1 to 4 and RH values from psychrometry charts for both conventional and clay tube coolers, their differences are marked in table 5, 6 and 7 respectively for DBT, WBT and RH.

Table 5 DBT measurements at different timings in a day

Sr	Time	Time Interval	Conventional Cooler	Clay Tube Cooler	Difference
1	11:30 AM	0 Minutes	33 C	34 C	+1 C
2	12:40 PM	70 Minutes	29 C	30 C	+1 C
3	01:50 PM	70 Minutes	24 C	28 C	+4 C
4	03:00 PM	70 Minutes	21 C	27 C	+6℃

Table 6 WBT measurements at different timings in a day

Sr	Time	Time Interval	Conventional Cooler	Clay Tube Cooler	Difference
1	11:30 AM	0 Minutes	24 C	24 C	0 C
2	12:40 PM	70 Minutes	20 C	23 C	+3 C
3	01:50 PM	70 Minutes	19 C	21 C	+2 C
4	03:00 PM	70 Minutes	18℃	20 C	+2℃

Table 7 RH measurements at different timings in a day

Sr	Time	Time Interval	Conventional Cooler	Clay Tube Cooler	Difference
1	11:30 AM	0 Minutes	48 %	45 %	-3 %
2	12:40 PM	70 Minutes	43 %	55 %	+12 %
3	01:50 PM	70 Minutes	65 %	53 %	-12 %
4	03:00 PM	70 Minutes	75 %	54 %	-11 %

V. CONCLUSIONS

- In can be observed from the results that in the continuous operation of clay tube air cooler in a closed area, the difference between the values of WBT and DBT is almost similar resulting in maintained values of RH nearly equals to the human comfort conditions.
- In conventional air cooler the results show that the differences between these parameters decreases with time hence RH value increases and stickiness and un-comfort condition occurs.
- It was observed from the rate of water supply in both coolers that in clay tube cooler because of the indirect contact between water and circulating air through clay tube surfaces approx 50% water can be saved for same operation time in comparison to conventional air cooler.
- In any conventional evaporative cooler about 25-30% of electricity is consumed by the pump for circulating water in the chamber. The energy efficient clay tube cooler does not use water-circulating pump resulting in direct saving of 25-30% of high-grade electrical energy.
- The effectiveness of the proposed system has been observed to increase with increase in dryness of environmental air.
- The clay tube system requires more space for installation, and further it can be feasible and economical option to replace conventional air-conditioning systems as there is no need of compressors, burners, or chemicals and only fans are required to move the air. This is proven promising technology for space conditioning of buildings.

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