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Design Modification for the Performance Optimization of Evaporative Desert Cooler

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Abstract: *In an evaporative cooling system, hot air from outside is forced through wet cooling pads by means of a motor-driven fan. The cooling pads are moistened continuously by a water pump that delivers water to it. The cooled down air is then blown into the building. Evaporative coolers lower the temperature of air using the principle of evaporative cooling. Evaporative cooling is the addition of water vapour into air, which causes a lowering of temperature of the air. The energy needed to evaporate the water is taken from the surrounding air in the form of sensible heat, which affects the temperature of the air, and convert it into latent heat. In Evaporative cooler, pads consist of excelsior (wood wool) inside containment net. Padding media plays a large part in cooling efficiency and water consumption. The purpose of this paper is to make an evaporative desert cooler more efficient and maintenance free, by making wood wool pad slide. They are assembled in such a manner that it can slide through u-channel and the top portion is duct which can also be placed or removed easily.*

Keywords: Evaporative Cooler, Human comforter, Modified Desert Cooler

I. INTRODUCTION

An evaporative cooler is a device that cools air through the evaporation of water. Evaporative cooling differs from other air conditioning systems, which uses vapour compression and absorption refrigeration cycles. Evaporative cooling exploits the fact that water will absorb a relatively large amount of heat in order to evaporate (that is, it has a large enthalpy and vaporization). The temperature of dry air can be dropped significantly through the phase transition of liquid water to water vapor (evaporation). This can cool air using much less energy than refrigeration. The cooling potential for evaporative cooling is dependent on the wet-bulb depression, the difference between dry-bulb temperature and wet-bulb temperature. In arid climates, evaporative cooling can reduce energy consumption and total equipment for conditioning as an alternative to compressor-based cooling. In climates not considered arid, indirect evaporative cooling can still take advantage of the evaporative cooling process without increasing humidity. Passive evaporative cooling strategies can offer the same benefits of mechanical evaporative cooling systems without the complexity of equipment and ductwork. In extremely dry climates, evaporative cooling of air has the added benefit of conditioning the air with more moisture for the comfort of building occupants. The advantages of evaporative air cooler is, less expensive to install and operate, good ventilation of air, and no harmful effect on environment. The present work aims on studying the modification to make it maintenance free & how the humidity could be controlled and improving the overall efficiency.

II. LITERATURE REVIEW

V. S. Shammy [1] in the paper talks about air cooler as one of the appliances that keeps the atmosphere cold. The basic concept of water cooling is to find a medium that can handle and transport heat more efficiently than air. Water has a very good ability to retain heat, in the meantime stay in a liquid form. It works on designing and developing a low-cost air cooler which can be used in houses and offices. The designing was done based on the quality function deployment (qfd) and product design specification (pds). This project gave an excellent opportunity to go through the end-to-end life cycle of a product.

Jose´ Rui Camargo et al [2] in this paper discussed the principle of evaporative cooling for human comfort and the operating principle of evaporative cooling system and the development of mathematical equations for determination of saturation effectiveness. This paper presents three methods that can be used as reference for efficient use of evaporative cooling systems, applying it to several Brazilian cities, characterized by different climates. Initially it presents the basic operation principles of direct and indirect evaporative cooling and defines the effectiveness of the systems. Afterward, it presents three methods that allows to determinate where the systems are more efficient. It concludes that evaporative cooling systems have a very large potential to propitiate thermal comfort and can still be used as an alternative to conventional systems in regions where the design wet bulb temperature is under 24ºC.

Vivek W. Khond [3] investigated the desert cooler performance using different cooling pad materials. Experimentation was conducted under varying speed of fan, and parameters like water consumptions, cooling efficiency, and air velocity were measured. Graph also revealed that water consumption rate for stainless steel wire mesh pad is very low as compared to other Pads. Maximum water consumption was observed in wood wool pad. Coconut coir and Khus pad also shown less water consumption rate as compared to conventional wood wool pad. At high fan speed, water consumption was lower for all pad materials. Maximum cooling efficiency was found in wood wool and Khus pad materials. Stainless steel wire materials pad shows poor cooling efficiency as compared to other pad materials but can be used where relative humidity was higher. As fan speed decreases, cooling efficiency of all pad materials increases.

Shoeb J. Inamdar [20] talks about comfort condition in terms of Temperature and Humidity and to minimize the water consumption. In this paper at a place of dry grass or cooling pads they used hollow bamboo as fluid conduit. In hollow bamboo water continuously flows without any restriction. Some slits or holes are provided on the bamboo to enable the water and air contact and ease the evaporative action after CFD flow simulation. After providing such geometry of contact the evaporation comes to optimism and the water consumption as well as humidity is reduced, the continuous flow of water inside hollow bamboo reduced the contact time of water with air. Due to this effect the humidity of air became comparatively less than direct contact evaporative cooler, also reduces the water consumption. This type of evaporative cooler was designed to facilitate efficient evaporation of the water and circulation of cooled air. It has been observed that the water consumption is decreased to almost half of the cooling pad when bamboo with such flow geometry is used. The DBT and RH remains in comfort zone with less water consumption.

Pratik Bhake[4] discuss the concept for cooling of air by designing an air cooler that does not contain water pump , while the other coolers present in the market which are equipped with water pump to wet the cooling material. They have also used air filters at the outer vents of the cooler so that they can able to clean as well as cool the air and also make it more hygienic. By designing the cooler in such a manner, they were able to wet the cooling material completely. It has been observed that by using the air filters on the side vents, the cooler even purifies the coming outlet air so than they can get cleaner air along with cool air. Better air -cooling capacity than conventional air cooler.

Mayank Harivilas Pal [5] work involves the design and manufacturing of the "evaporation cooling air cooler cooling with dehumidification and heating" which will not increase the humidity of air. It maintained the room at comfort conditions by using the silica gel to reduce the humidity of air. This cooler was invented to work in both the season winter and summer. In winter season, cooling module is stop and heating module is on, so that air is heated by heater and to ultimately increase the temperature of air. In summer season, cooling module is on and heating module is off, it has been observed that it ultimately decreases the temperature of air up to 10°C. In summer season silica gel is also be used to reduce the humidity of air. By performing this experiment, it was concluded that, this project can be used in summer and winter both seasons, in summer it can maintain temperature of the atmosphere around 24°C which is most favourable for human being.

Ritesh W. Dhone [6] talks about, a new model of direct evaporative cooler having a good aesthetic look and light in weight will be fabricated. The performance of this fabricated cooler was analyzed by using cooling pads of four different materials such as cellulose paper pad, wood fibers, wood wool (Aspen) and coconut fibers. Apart from these four types of cooling pads, also the performance of direct evaporative cooler was analyzed by using a combination of three different types of cooling pads simultaneously on three sides of the cooler. Two most important terms considered in this analysis are temperature and humidity. The readings of these two terms had been taken for each type of cooling pad and also, the further calculations had done based on these readings. It has been observed that this combination of three different types of cooling pads provides a good cooling efficiency with least increase in humidity.

Sachdeva A. [7] in this paper talks about energy and exergy analysis of direct evaporative cooling system. In this study ambient temperature, saturation specific humidity of the process and pressure at the end of the process is considered as the dead state. Variations in wet-bulb Saturation Effectiveness, change in thermal exergy, change in chemical exergy, total inlet exergy, total outlet exergy and exergy efficiency is analysed for pads of different thickness with constant face velocity. It was observed that for a given thickness of pads exergy efficiency does not change as wet bulb saturation efficiency changes.

Piyush Shrivastava [8] talks about using the water for the evaporation purpose, which leads to decrease the temperature of the air also containing the most economically environmental effective system. In this review paper of evaporating cooling technology, methods are studied for the commercial and comfort purposes. Indirect evaporative coolers had shown higher values of effectiveness and more economically operated in the terms of energy consumption saving, particularly the M-Cycle, which is based on dew point IEC system.The combined system of direct and indirect cooling system have similar performance or even the higher but their system consist of higher initial cost and the major problems like noise & vibrations, pressure loss and friction loss. Recent work on experimentations and the Methodologies suggested by the author have shown the considerable potential towards enhancing the performance and cooling capacity of the system for building cooling.

III. DESIGN SPECIFICATION OF THE SYSTEM

The design specifications of the evaporative desert cooler are as follows:

WATER PUMP SPECIFICATIONS	
Voltage	AC 220-50 Hz
Power	18W
Maximum Flow	1150Lph
Maximum Height	6Ft
MOTOR SPECIFICATIONS	
Voltage	220-230V
Speed	1340 RPM
Frequency	50 Hz
Efficiency	52%
Rated output	180W
F.L.C	1 A MAX
P. F	0.90
FAN BLADES	18 inches
DUCT	24.8 inch (4 side each)
TEMPERATURE HTC-2	
Temperature measuring range	-10%~70% ℃ (14 °F~158°F)
Temperature measuring accuracy	1℃(1.8°F)
Temperature Resolution	±1℃(0.2°F)
Humanity measuring range	10%RH-99%RH
Humanity measuring accuracy	±5%RH
Humanity resolution	1%
Used battery	AAA1.5V

Temperature humidity display	°C/°F
WATER TANK CAPACITY	110 L
COOLING PAD MATERIAL	Wood wool
WOOD WOOL PANEL	1. 42.5×24.6 inch 2. 42.5×23.6 inch
U-CHANNEL	
1. Water passing through	24.5 inch (4 side each)
2. Wood wool panel sliding	23 inch (4 side each)
ROD LENGTH	43 inch (4 side each)

Table: Design Specification

IV. WORKING METHODOLOGY

- The evaporative cooler works on the principle of evaporation. The working of the cooler is simple. The working can be so explained as the surrounding air pulled in by the cooler, the air gets in contact with the water and the water content of the air increases. Due to this increase in water content the air gets cooled because of the air losses its heat.
- The working of the evaporative cooler and regular cooler is similar to each other. All the evaporative coolers have a cooling medium in it. In our cooler we have used wood wool as it is cheap and readily available everywhere.
- The working principle of this type of cooler is that it pulls the air inside and then this air is forced forward at a long distance with the help of fan. The speed of motor can be controlled using the regulator if attached to the cooler.
- The water pump which is submerged in the water tank, transfers the water from low level to high level. This water runs through the evaporative cooling pads, which tends to give fresh air i.e. Cool air.

4.2 TESTING

The direct saturation efficiency, ∈, measures in what extent the temperature of the air leaving the direct evaporative cooler is close to the wet-bulb temperature of the entering air. The direct saturation efficiency can be determined as follows:
+3

$$\epsilon = \frac{T_{e,db} - T_{l,db}}{T_{e,db} - T_{e,wb}}$$

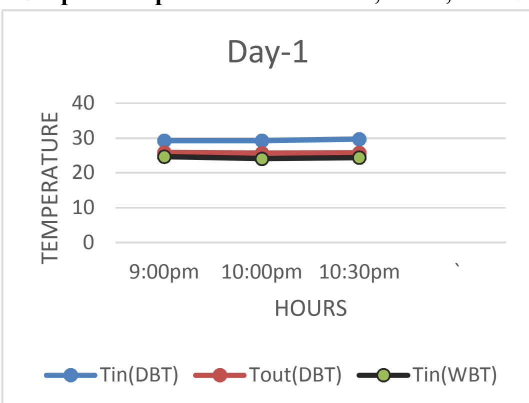
Where ∈ = direct evaporative cooling saturation efficiency (%)
T_e,db = entering air dry-bulb temperature (°C)
T_l,db = leaving air dry-bulb temperature (°C)
T_e,wb = entering air wet-bulb temperature (°C)

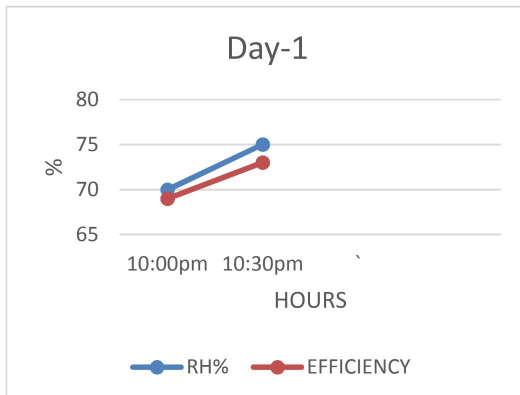
Sr no.	DBT			WBT		EFFICIENCY (∈) %
	Time	T_e	T_l	T_e	RH%	∈= [100×(T_e,db - T_l,db /T_e,db - T_e,wb)]
Day-1						
	9:00pm	29.3	25.9	24.7	73	73
	10:00pm	29.3	25.7	24.1	70	69
	10:30pm	29.7	25.8	24.4	75	73
Day-2						
	11:00am	34.4	27.1	25.1	44	78
	12:00pm	35.9	26.9	25	37	82

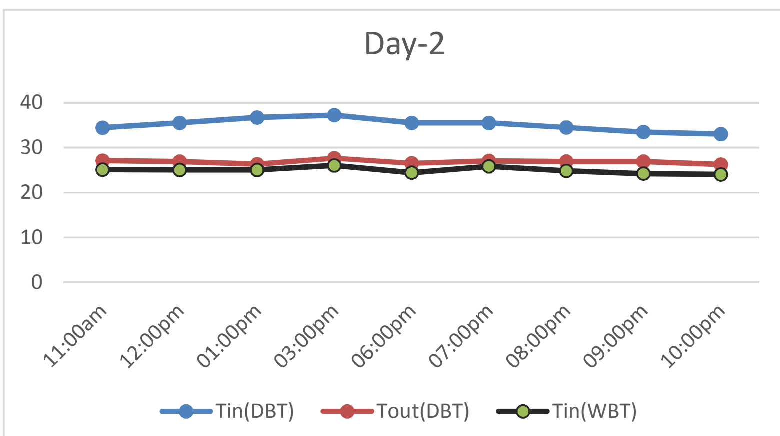
	1:00pm	36.7	26.3	25	35	88
	3:00pm	37.2	27.6	26	31	85
	6:00pm	35.5	26.5	24.4	37	81
	7:00pm	35.5	27.2	25.8	41	85.5
	8:00pm	34.5	26.9	24.8	41	78
	9:00pm	33.5	26.9	24.2	46	70
	10:00pm	33	26.2	24	44	75
Day-3						
	11:00am	33.7	27.4	26	46	81.8
	12:00pm	34.2	27	25.5	39	82
	1:00pm	36	26	25.2	19	87
	9:00pm	35.3	28.5	27.6	35	88.3
	10:00pm	33.7	26.1	25.2	30	89.4

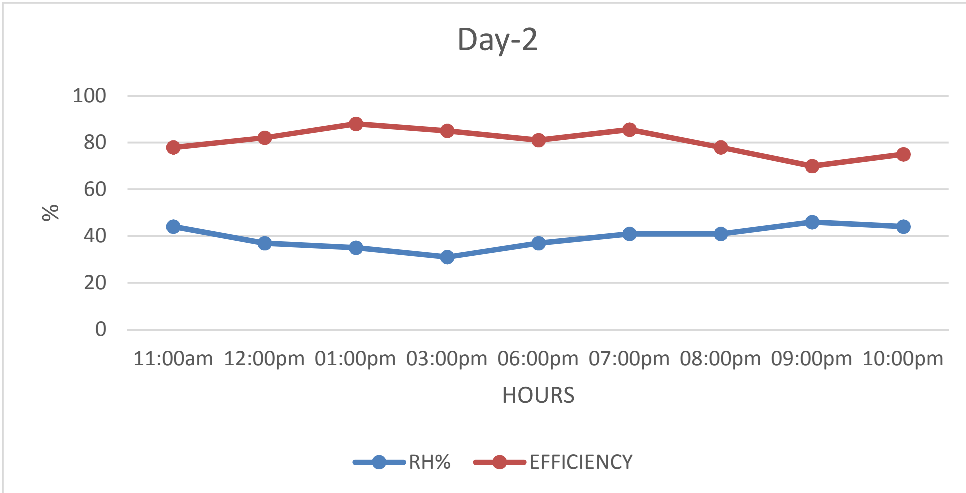
Table: Observation table for efficiency of evaporative cooler

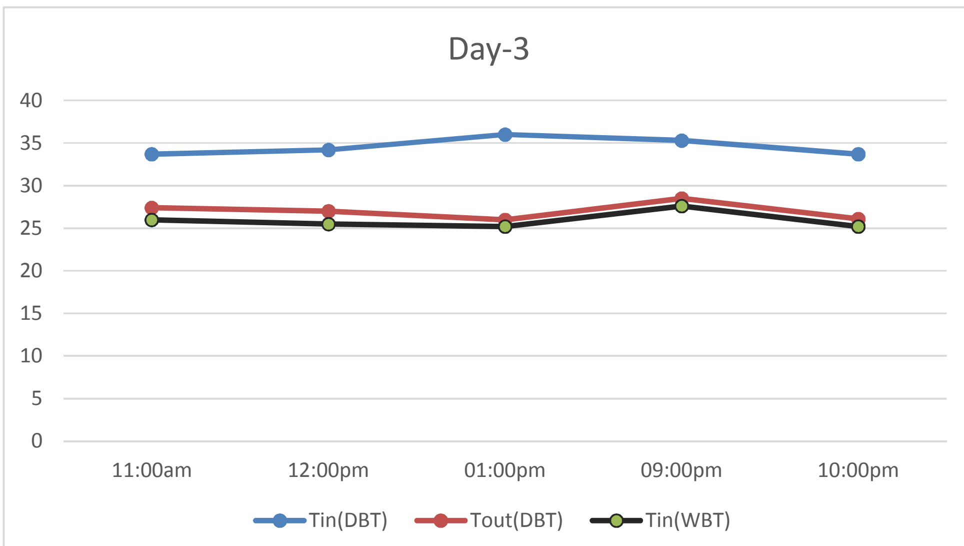
4.3 Graphical representation of DBT, WBT, RH & EFFICIENCY

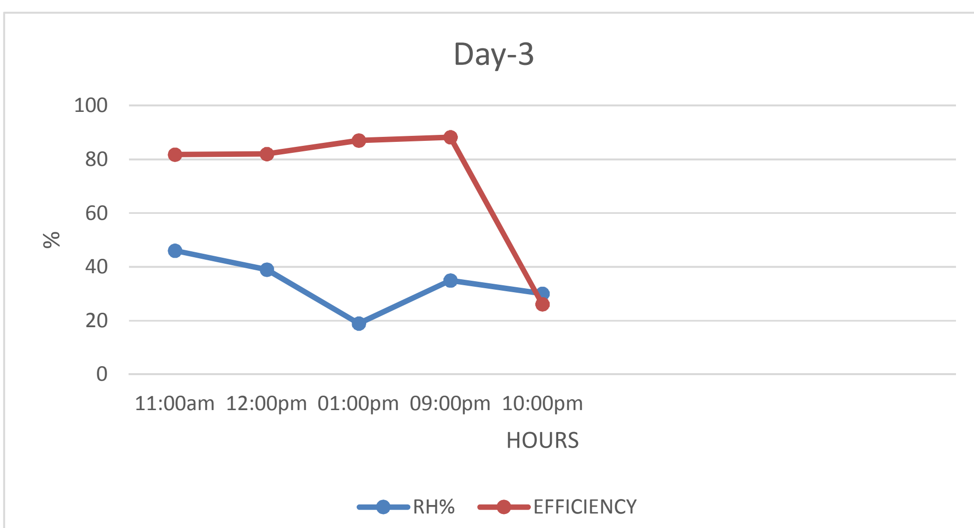







Day-2
100
80
60
40
20
0
%
11:00am 12:00pm 01:00pm 03:00pm 06:00pm 07:00pm 08:00pm 09:00pm 10:00pm
HOURS
RH%
EFFICIENCY


Day-3
40
35
30
25
20
15
10
5
0
11:00am 12:00pm 01:00pm 09:00pm 10:00pm
Tin(DBT)
Tout(DBT)
Tin(WBT)


Day-3
100
80
60
40
20
0
%
11:00am 12:00pm 01:00pm 09:00pm 10:00pm
HOURS
RH%
EFFICIENCY

V. RESULTS

An evaporative cooler is a device that cools air through the evaporation of water. Evaporative cooling differs from other air conditioning systems, which uses vapour compression and absorption refrigeration cycles. Evaporative cooling exploits the fact that water will absorb a relatively large amount of heat in order to evaporate (that is, it has a large enthalpy and vaporization). From Table 6.2 it is observed that, modified desert cooler has the efficiency from 83% - 89% and the wood wool panels sliding through the cooler makes it easy to assemble, therefore evaporative cooler is maintenance free.

VI. CONCLUSION

- As less number of parts are coming in contact with the water the chances of rust is reduced and life of the cooler is increased.
- Because of its modified design, it is easy to change the wood wool.
- More hygienic than the conventional air cooler as there is no water falling outside the cooler, which results no leakage of water.
- Better air-cooling capacity than conventional air cooler.
- By performing this experiment can conclude that, this project can be used in summer season, in summer it can maintain temperature of the atmosphere around 24°C which is most favourable for human being.

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