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Design and Analysis of Regenerative Air Cooler

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Abstract- Regenerative air cooler is a device which is capable of controlling humidity as well as temperature within a confined area. The main motive is to restrict the amount of water droplets mixing with the output air, which is the main reason of moisture generation. So by this project we are performing the same task to our best. Although a lot of modification is required to launch this device uniformly but then also we have done our best job to present it as a model **.**We have used blower, a motor, a water pad, a pump, a water tank and a heat exchanger in this cooler.1 blower is used to throw the air outside and another is used to suck the air and send it at heat exchanger. A motor is used to rotate the blowers. A water pad is being used to cool the air air Furthermore a tank is for storage and a pump is for transmission of water. Regenerative air cooler is a suck the air and send it at heat exchanger. A motor is used to rotate the blowers. A water pad is being used to cool device which is capable of controlling humidity as well as temperature within a confined area.

Index Terms- Heat Exchanger, water tank , motor, water pad, pump, blower.

1 INTRODUCTION

This project involve making a regenerative air cooler that would enable the user to control temperature as well as humidity of the incoming air .This imparts properties similar to that of an AC, except that this device is based on the evaporative cooling principle of desert cooler. This entails less cost of the device. The principle objective is to make the performance of this device as possible to that of an air conditioner. The device employs the normal components used in desert cooler such as pump, water pads, water basin in addition to heat exchanger and blower. The blower used in this model provides the draught of cool air into the room with the inlet air undergoing cooling blows a part of this cool air into the heat exchanger. The cooling air being passed into the heat exchanger flows through a water pad, since for this air temperature reduction is the only concern. This air will be thrown into the atmosphere after providing cooling action in heat exchanger. This removes the concern of controlling humidity in this stream of air.

The cooling action of the heat exchanger keeps the specific humidity of the incoming air constant. This cooling is helpful in reducing the moisture content of the final exiting air because cool air absorbs comparatively lesser moisture. Since the cooing in the heat exchanger is directly dependent on the temp of the cooling fluid (air), the moisture content of the final air can be controlled to some extent by greater cooling in the heat exchanger phase.

Hence the temp control and moisture control are interlinked with one another. This is the drawback of this device with respect to an air conditioner. There are several places of application for regenerative air cooler. Indian industries are often unable to provide their workers with proper work environment during summers because of the prohibitive expense incurred in getting their work units air-conditioned.

Traditional desert coolers do not quite solve the purpose of cooling a big hall size work place. Regenerative air cooler is an affordable and effective solution to this problem. It uses a blower in place of the fan of desert cooler and hence its electricity consumption is not too larger than that of a cooler. The performance of regenerative air cooler is much superior to that of a desert cooler, as will be confirmed by the design calculations and demonstrated. There are prospects of improving the efficiency of regenerative air cooler still further by improving the design of heat exchanger. Most of these modifications can be implemented in a cost effective manner, without resorting to the costly alternative of using a costly copper heat exchanger.

2 LITERATURE RIVIEW

2.1 A General Theory of Wet Surface Heat Exchangers and its Application to Regenerative Evaporative Coolinig

I.L Maclaine-cross [1] ,suggested that wet surface heat exchangers such as cooling towers and wet plate heat exchangers are important in air conditioning. A linear approximate model of wet surface heat exchangers is proposed. The equations of the model are rearranged, enabling solutions for wet bulb depression and wet bulb temperature to be obtained independently, by analogy from published solutions for dry bulb temperature in dry surface heat exchangers. Performance predictions by this method for a cross flow cooling tower are found to agree with those from a prevous finite difference solution. Published performance measurements for a crossflow wet plate heat exchanger are lower than predicted by the method possibly due to poor wetting or excessive water flow. Excellent performance is predicted for a proposed regenerative evaporative cooler using such an exchanger.

2.2 Experimental study of a counter flow regenerative evaporative cooler with finned channels

Dae-Young Lee [2] ,suggested that a regenerative evaporative cooler has been fabricated and tested for the performance evaluation. The regenerative evaporative cooler is a kind of the indirect evaporative cooler comprised of multiple pairs of dry and wet channels. The air flowing through the dry channels is cooled without any change in the humidity and at the outlet of the dry channel a part of air is redirected to the wet channel where the evaporative cooling takes place. The regenerative evaporative cooler fabricated in this study consists of the multiple pairs of finned channels in counter flow arrangement. The fins and heat transfer plates were made of aluminum and brazed for good thermal connection. Thin porous layer coating was applied tothe internal surface of the wet channel to improve surface wettability. The regenerative evaporative cooler was placed in a climate chamber and tested at various operation condition.

The cooling performance is found greatly influenced by the evaporative water flow rate. To improve the cooling performance, the evaporative water flow rate needs to be minimized as far as the even distribution of the evaporative water is secured. At the inlet condition of 32 °C and 50% RH, the outlet temperature was measured at 22 °C which is well below the inlet wet-bulb temperature of 23.7 °C.

2.3 Flow reversing regenerative air dryer

Arthur R.Grix [3] ,suggested that a flow-reversing, regenerative, desiccant air dryer system absorbs moisture, oil droplets, and carbon particles from the incoming air during compression in a compressed air system. Once sufficient air pressure has been attained in an air pressure reservoir, control valves direct the flow of atmospheric-pressure air, heated by passing through the warm compressor cylinder, in a reverse direction through the air dryer. The reverse flow of heated, atmospheric pressure air both purges the trapped oil, carbon particles, and condensed liquid water and removes the moisture from the desiccant.

2.4 Desiccant cooling air conditioning

R.Z Wang [4] ,suggested that the principles underlying the operation of desiccant cooling systems are recalled and their actual technological applications are discussed. Through a literature review, the feasibility of the desiccant cooling in different climates is proven and the advantages it can offer in terms energy and cost savings are underscored. Some commented examples are presented to illustrate how the desiccant cooling can be a perfective supplement to other cooling systems such as traditional vapour compression air conditioning system, the evaporative cooling, and the chilled-ceiling radiant cooling. It is notably shown that the desiccant materials, when associated with evaporative cooling or chilled-ceiling radiant cooling, can render them applicable under a diversity of climatic conditions.

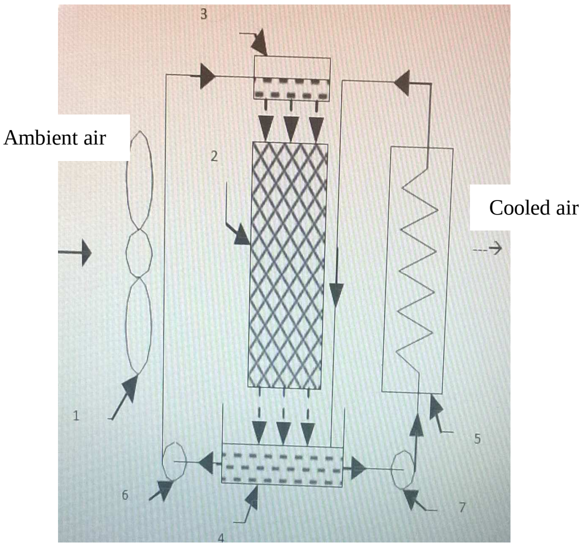
2.5 Modelling of indirect evaporative air coolers

P.J Erens and A.A Dreyer [5] ,suggested that the modelling of indirect evaporative air coolers is discussed and three calculation models are described. Sample calculations show that the optimum shape of the cooler unit would result in a primary to secondary air velocity ratio of about 1.4, assuming that the primary and the secondary air mass flow rates are the same and that the same plate spacings are used on the primary and secondary sides. In conclusion it is found that the simplified model gives good results and is recommended for the evaluation of smaller systems and for initial design purposes while the more sophisticated methods should be used for more accurate performance prediction.

3 WORKING PRINCIPLE:

3.1 Principle Working of Regenerative Air Cooler

The working of regenerative air cooler can be understood through the following diagram depicting the flow of air within the device



NAMING

1 – Air Blower
2 – Cooling Pad
3 – Water Distributer
4 – Water collecting tank
5 – Heat Exchanger
6 – Circulating pump for Direct cooling
7 – Circulating pump for heat exchanger

3.2 Air Circulation Process

The ambient air is pulled into the cooler due to the suction effect creating by rotating blower. The incoming air first flow through the heat exchanger where it undergoes first stage of cooling. Then it flows through the wetted water pad , undergoing evaporative cooling in the process. A portion of this evaporative cooled air flows out of the cooler, while the blower blows the remaining portion to the atmosphere. This causes the air to loose its kinetic energy and acquires greater static pressure. This air then flows across water pad for a second time undergoing further evaporative cooling. It then flows through the heat exchanger and exchange heat with the atmospheric air. The temperature of the ambient air decrease and flows across the water pad, undergoing evaporative cooling in this process then blower blow into the room with controlled relative humidity .The higher pressure of this air sustains the forward motion of this air through the heat exchanger. This stream acts as the cooling stream in the heat exchanger, cooling the incoming stream of air. After cooling, this stream gets heated and is rejected into the atmosphere.

4. EQUATIONS AND CALCULATION:

4.1 Calculation for Blower

Entering Air velocity, in=6.62 m/sec
Inlet area, Ain=Π/4(.24^2) ……Eq(1)
Ain=.045 m^2
Q=Ain×vin …………………...Eq(2)

= 0.297 m^3/sec.

= 17.874 m^3/min.

by applying bernaulli's equation

Q=CONST
Q= .297 m^3/sec=17.874 m^3/min
Outlet area, Aout= Π/4(.32^2)= .0803 m2 ……Eq(3)
Exit air velocity (air to room), Vout=Q/A=.297/.0803= 3.72 m/sec …………………….Eq(4)

4.2 Calculation for Water Pad

DBT1=38°C
WBT1=21°C
RH1=20%
H1=60.25 KJ/Kg of air
Spe. Vol, Vs1=.89 m^3/Kg
DBT2=36.5°C
WBT2=27°C
RH2=50%
H2=85 KJ/Kg of air
SPE. VOL, Vs2=.91 m^3/Kg
Mass of Air Supplied
m_a=Q/Vs = 17.874/.91 = 19.64 Kg/min
Ma=.327 Kg/sec ……..…….Eq(5)

4.3 Calculation for Heat Exchanger
T_{H1}=38°C
T_{H2}=?
T_{C1}=36.5°C
T_{C2}=?
Capacity rate of air, (C) min=m_a

$$N = \frac{(UA)}{(C)min}$$ …………..Eq(6)

$$U = \frac{1}{\frac{2}{h}+\frac{l}{k}}$$ …………………..Eq(7)

H=40, l=.0005, K for Al =205
U= 1/(2/40)+(.0005/205) = 39.996
A= 6×2 Πrh =.0603
UA=39.996×.0603=2.411

$$N = \frac{(UA)}{(C)min}$$

$$N = \frac{(16.92)}{(.2397)min}$$

=10.05

$$\varepsilon = \left(\frac{1}{1-\exp(-N)} + \frac{.1}{1-\exp(-NC)} - \frac{1}{N}\right)^{-1} \quad \ldots\ldots\ldots\text{Eq(8)}$$

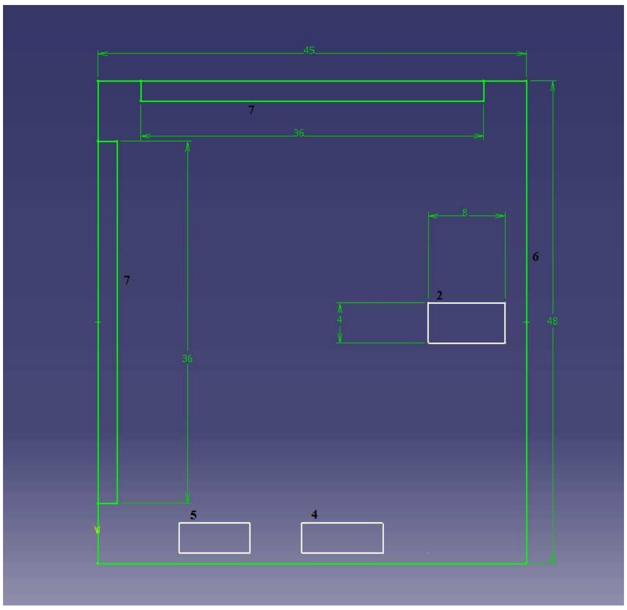
$$\varepsilon = \left(\frac{1}{1-\exp(-\ 10.0\ )} + \frac{.1}{1-\exp(-\ 10.0\ \times .1)} - \frac{1}{10.05}\right)^{-1}$$

ε=.526
T_{H1}=38°C
T_{H2}=?
T_{C1}=36.5°C
T_{C2}=?

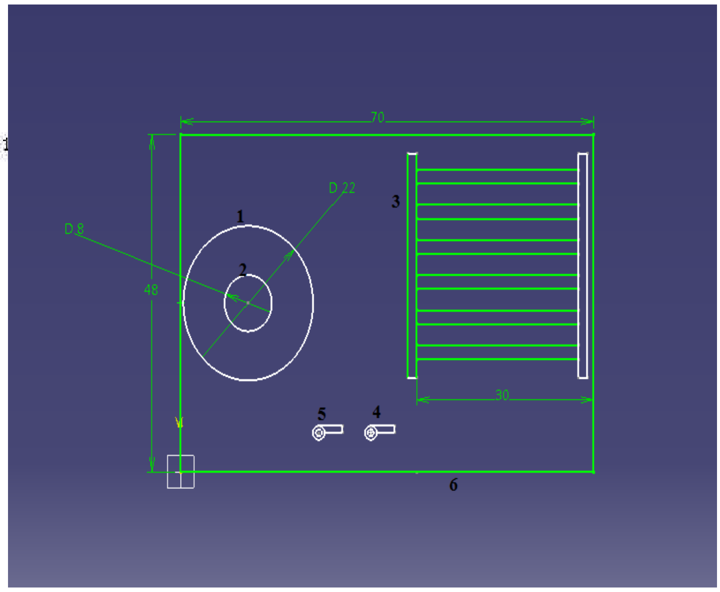
$$\varepsilon = \frac{Tc2-Tc1}{TH1-Tc1} \quad \ldots\ldots\ldots\ldots\text{Eq(9)}$$

(38-36.5) ε =38- T_{H2}
(38-36.5) ε =38- T_{H2}
1.5× .526= 38- T_{H2}
0.789 = 38- T_{H2}
T_{H2} =37.211 °C
0.789 = T_{C2}-36.5
T_{C2}=37.289°C
Temp. Of atm air, TH1=38°C
Temp. Of treated atm air, TH2=37.211°C
Temp. Of cooled air from water pad, TC1=36.5°C
Temp. Of exit air, T_{C2}=37.289°C

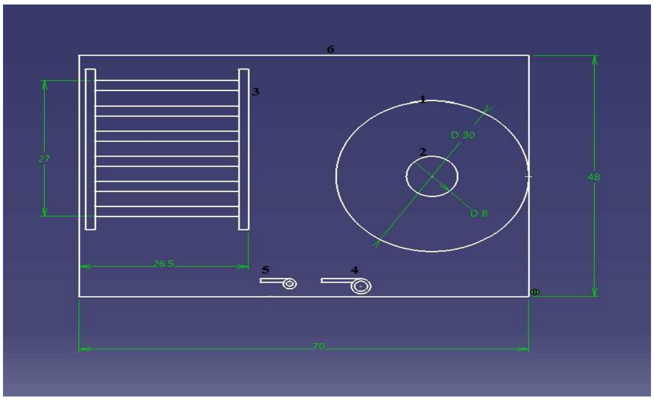
5. FIGURES, TABLES AND PHOTOGRAPHS:
5.1 Design of Regenerative air cooler using catia software
5.1.1 TOP VIEW



5.1.2 R.H.S VIEW



5.1.3 L.H.S VIEW



1. Outgoing air from Blower
2. Blower
3. Heat Exchanger
4. Pump For Direct Cooling
5. Pump for Heat Exchanger
6. Water Tank
7. Water Pad

5.2 Tabulation

5.2.1 Final results of this experiment is as follow:-

5.2.2The range of the results of this experiment is as follows:-

	Temperature (C)	Humidity (RH %)
Ambient air	36-40	20-25
Exit air	33-37	50-60

5.3 Photo of Regenerative Air Cooler:-

	Temperature (C)	Humidity (RH %)
Ambient air	38	20
Exit air(air to room)	36.5	50

6. RESULTS AND GRAPHS:-

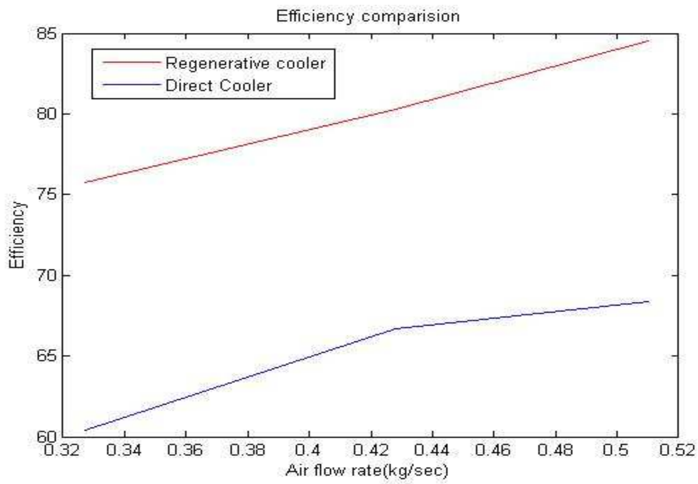
6.1 Variation of effeciecy with mass flow rate

Air flow rate(kg/sec.)	*Efficiency of direct evaporative cooler(in %)*	*Efficiency of regenerative air cooler(in %)*	*% increase in efficiency*
0.327	60.42	75.72	20.44
0.428	66.71	80.25	23.81
0.51	68.40	84.52	26.38

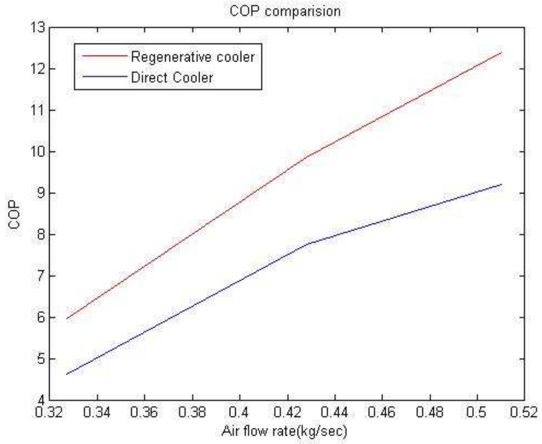
6.2 variation of COP with mass flow rate

Air flow rate(kg/sec.)	*COP of direct evaporative cooler*	*COP of regenerative air cooler*	*% increase in COP*
0.327	4.62	5.96	20.44
0.428	7.76	9.85	23.81
0.51	9.21	12.37	26.38

6.3 Graphs:-



Graph no. 1: Variation of efficiency with Air Flow Rate.



Graph no. 2: Variation of COP with Air flow rate

7. CONCLUSION

It may be concluded that there is considerable improvement inefficiency and COP (20-27 %) of direct evaporative cooler with regenerative heat exchanger. Percentage increase in efficiency is almost same for each flow rates. The cost comparison shows that there is slight increase in cost because of an additional pump and a heat exchanger but increase in cooling efficiency is substantial. Thus regenerative evaporative cooler is advantageous for providing more cooling compared to an ordinary direct evaporative cooler, which can make the cooler more useful for providing thermal comfort in residential and commercial buildings. It may also attract more people for maximum utilization of such a low energy consuming device leading to energy conservation.

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