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Modified Air Cooler with Split Cooling Unit

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Abstract: ***Energy consumption all over the world is increasing rapidly and we need to develop ways to conserve energy for future requirement [1]. For our comfort conditions generally we use an air conditioner, it uses a vapour compression refrigeration system. This refrigeration system consumes very large amount of power (about 1.5 KW), also the cost of this system is high. So the other option for maintaining comfort is evaporative cooler. The cost of evaporative cooler is less than that of AC; also it consumes less power than AC. The main drawback of evaporative cooler is that the air supplied by the cooler contains the large amount of humidity. Due to which when an individual sits in the air of the cooler, he/she feels stickiness on the body which is not comfortable for him/her. This project work involves the manufacturing and design of split cooling unit which will cool air but not increase its humidity. It will maintain the room at comfort conditions by recirculating the air in the room through split unit.***

Keywords: Evaporative cooler, split cooling unit, option for AC

1. Introduction

Due to great consumption of energy in buildings, there are increasing demands to design energy-efficient heating, ventilation, and air-conditioning (HVAC) equipments and systems for buildings.[2] The evaporative cooler was very popular in the twentieth century; many of these, made the use of wood wool pads to bring a large volume of water in contact with moving air to allow evaporation to occur. A typical design includes a water reservoir, a pump to circulate water on the pads and a fan to supply air through the pads and into the cooling space. This design and this material remained constant in evaporative coolers in some areas where they are also used to increase humidity. In India, the Union ministry of power's research pointed out about 20-25% of total electricity utilized in government buildings gets waste due to non-productive design, resulting in an annual energy related financial loss of about Rs.1.5 billion. Conventional heating ventilation and air conditioning systems consume approximately 50% of building energy. Conventional vapour compression air conditioning systems consume a large portion of electrical energy which is produced mostly by fossil fuels. This type of air conditioning is therefore neither eco-friendly nor sustainable. [1]

2. Basic Principal

Evaporative cooling is a concept in which evaporation of a liquid take place, generally into surrounding air, thereby cooling the air or liquid in contact with it. The pads of evaporative cooler are brought in contact with water. Then a fan draws air through these pads, the air rejects its heat to the water present on the pads and become cool. Latent heat is needed to evaporate the liquid; it is taken from the air. When the evaporation of water is taken into account, the wet-bulb temperature is a measure of the potential for evaporative cooling than that of dry bulb temperature. More the difference between the two temperatures, larger the evaporative cooling effect. When both the temperatures are same, there is no evaporation of water in air; hence there is no cooling effect. The main drawback of evaporative cooler is that it increases the humidity, due to this after sometime we sit in the air of evaporative cooler we feel stickiness our skin. If this drawback has been overcome then evaporative cooler will be a better option for high power consuming and expansive AC. In this design we have implemented a split cooling unit which is coupled to the conventional evaporative cooler. This split unit will take water from the tank of conventional evaporative cooler, circulate the water through its heat exchangers, and will supply air through heat exchangers. Thus air will become cool and its humidity will not increase. There is natural evaporative system to cool our body called as perspiration [4].

3. Modified Design

The modified design is as shown below in fig no.1. The main modification is the split cooling unit. As shown below the split unit is attached to conventional evaporative cooler. The split unit is a simple rectangular duct. In this duct there are three heat exchangers in series. The water from regular evaporative cooler is cooled due to evaporative action. This cool water from the tank is circulated through the split unit. The water from the tank is firstly pumped to the common rail and then it is supplied to the heat exchangers. The purpose of evaporative cooler is only to cool water in its tank.

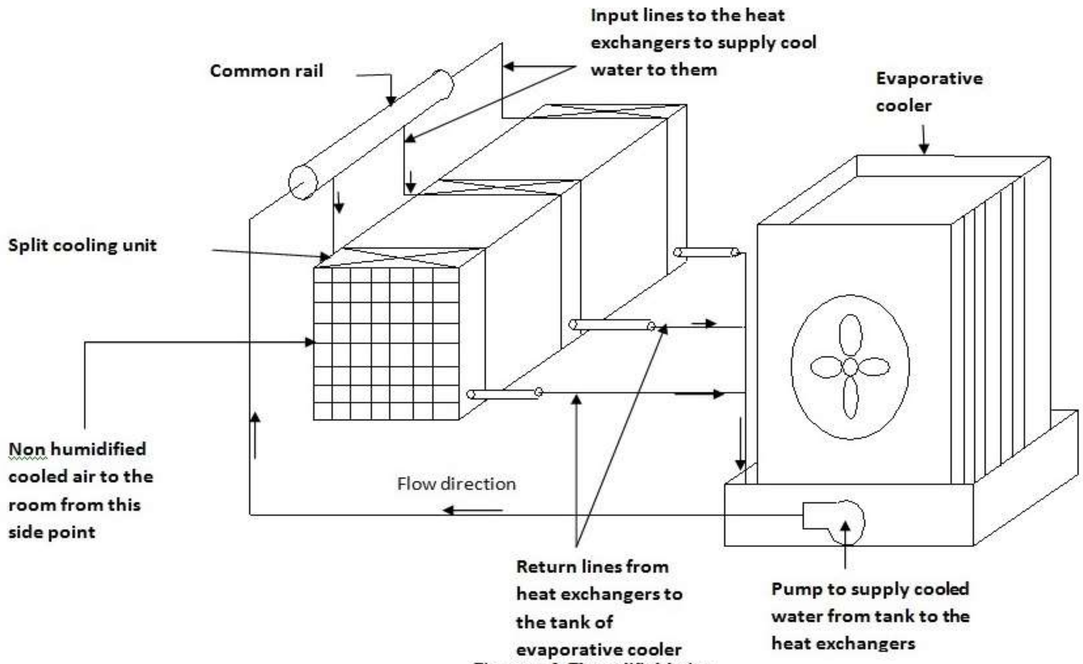

Figure no. 1. The modified design

The split unit has a fan which will supply air to the room. The air thus supplied will be cool and non humidified .Only split unit will be kept into the cooling space and the evaporative cooler will not thus the split unit will take air from room and after cooling it the unit will supply air back to the room thus due to this recirculation there will be more cooling effect. The air from evaporative cooler can be used to cool another space where humidity is desired. This system requires very less power (130 W) than that of AC. Also the cost of system is very less than that of AC.

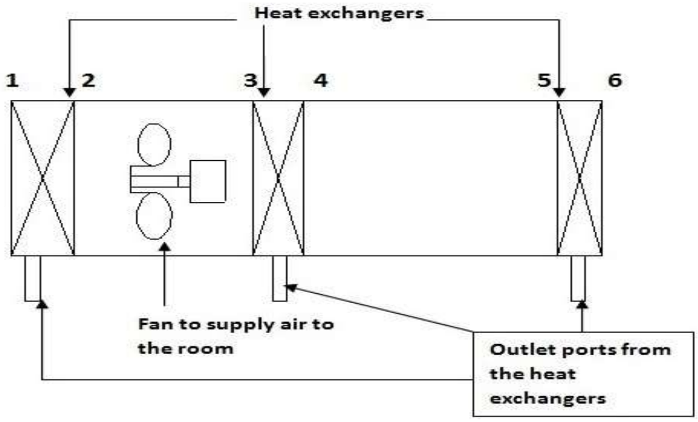

Figure no.2. Experimental setup

4. Experimental setup

The experimental setup is as shown in fig. no.2 above. Six thermocouples are attached at inlet and exit of each of three heat exchangers and the readings are taken at various times of a single day. The numbers 1 to 6 shown in figure no.2 indicate the position of thermocouples. The table no. 1 shows the readings of various thermocouples at different times of a day.

Sr. No	Time	Temperature of air at various points of split unit						T_{room}	T_{amb}
		1	2	3	4	5	6		
1	9.00am	29.1	29.3	29.3	29.5	29.5	29	29	29.5
2	10.00am	25.4	25.9	25.9	26.3	26.3	26.9	26.9	30
3	11.00am	25.3	25.6	25.6	26.1	26.1	26.4	26.4	31
4	12.00pm	25.2	25.7	225.7	26.1	26.1	26.3	26.3	32.4
5	01.00pm	25.2	25.4	25.4	25.7	25.7	26.2	26.2	34
6	02.00pm	25.3	25.7	25.7	26.3	26.3	26.7	26.9	36
7	03.00pm	25.3	25.7	25.6	26.2	26.2	26.8	26.8	38
8	04.00pm	25.2	25.8	25.6	26.1	26.1	26.6	26.8	40.3
9	05.00pm	25.1	25.5	25.4	25.9	25.9	26.3	26.3	38.2
10	06.00pm	25.1	25.5	25.3	25.6	25.6	25.9	25.7	35.1
11	07.00pm	25	25.4	25.1	25.3	25.3	25.5	25.5	31.5
12	08.00pm	25	25.4	25.1	25.3	25.3	25.7	25.5	28
13	09.00pm	25	25.3	25.1	25.3	25.3	25.7	25.4	27.2

The table no. 1 shows the readings of thermocouples collected during the experiment.

T_{room}= Room temperature.

T_{amb}= Ambient temperature.

All values are in degree Celsius.

5. Calculations for Heat Exchanger

Length of tube:
Nu= Nusselt number
Pr= Prandtl number
C_p= Specific heat of air in kj/kg °K
h= heat transfer coefficient in W/m^2°C

Firstly finding nusselt number,

$$Nu = C\, Re^n\, Pr^{1/3} \quad (1)$$

For circular tube, C=0.027 and n= 0.805

Considering diameter of tube as 5 mm.
Mean temperature of air= (27+30)/2= 28.5°*C*,

The properties of air at 28.5°*C* are,
C_p= 1.006 kj/kg°k, *Pr*=0.712, μ=0.00001865

The Reynolds's number can be find out from equation,

$$Re = \frac{\rho v d}{\mu} \quad (2)$$

The value of Re from eqn. (2) we got is 5597.85
Thus the value of nusselt no. from eqn. (1) is 250.68

The heat transfer coefficient '*h*'can be calculated from,

$$Nu = \frac{hd}{k_f} \quad (3)$$

The value of '*h*' from eqn. (3) we got is 661.29W/m^2°c.
Using eqn. for heat transfer,

$$Q = mc_p\, dt \quad (4)$$

Then by using eqn. of heat transfer due to convection,

$$Q = h\, A\, dt \quad (5)$$

Tube length can be find out.
The length of tube is 580cm per heat exchanger.

5.1 Calculation for heat rejected particular time in all three heat exchangers

For first heat exchanger,
Here,
Td_1= Temperature of air at inlet of heat exchanger= 25.8°C
Td_2= Temperature of air at outlet of heat exchanger= 25.2°C

H_1= Enthalpy of air at inlet of heat exchanger= 51.5 kj/kg of dry air

H_2= Enthalpy of air at outlet of heat exchanger= 50 kj/kg of dry air

Q = Heat rejected in kj/kg of dry air
Q= H_1-H_2 (6)
=51.5-50= 1.5 kj/kg of dry air

For second heat exchanger,
Td_1=26.1, Td_2=25.6, H_1=50.2, H_2=50
Q= 50.2-50 [from eqn. (6)]
=0.2 kj/kg of dry air

For third heat exchanger,

Td_1=26.8, Td_2=26.6, H_1=53.5, H_2=52
Q=53.5-52 [from eqn. (6)]
=1.5 kj/kg of dry air

The geometric arrangement of heat exchangers is as shown in fig.2 typically one fluid (air) moves over the tubes in cross flow, while other fluid (water) at relatively low temperature passes through the tubes. The rows of tubes are staggered in direction of air flow. The flow condition across tube blank is influenced by boundary layer separation effect and by wake interaction which influence convection heat transfer.

The other components of the system are as follows-
Fan-
There are two fans are used in this system. One for the evaporative cooler and the other is fitted in the split unit.
Specifications of fan-
Size-152.4 mm
1500rpm, single phase, 4 poles, 50 Hz, AC
Power consumption- 40 W each.

Submersible pump-
There are two submersible pumps used in the system. The first pump is for evaporative cooler and the second is for circulating water from tank of cooler to the split unit.
Specifications of the pump-
Power consumption- 20W each
Voltage- 220V AC
Outlet nozzle size- 1/2"
Maximum head-2m

5.2 Calculation for COP of the system:

Table 2: Values of enthalpy and humidity from psychometric chart

Sr. no	DBT. (°C)	WBT (°C)	Enthalpy (KJ/KG)	Relative humidity
1.	42	35	105	50
2.	23	17	50	50

The values are collected in table no. 2 to find COP

The values are taken from psychometric chart,

COP= Energy supplied/ Energy used

$$COP = m\,(H_1 - H_2) \quad (7)$$

Where,
m= mass flow in kg/sec

H_1= Initial enthalpy of air in kj/kg of dry air = 105

H_2=Enthalpy of air at outlet of split unit i.e. final enthalpy in kj/kg of dry air = 50

The COP is = 7

The results are been plotted on psychometric charts as shown in figure no. 3 below, the relative humidity is constant at 50% and temperature reduces from 42°C to 23°C.

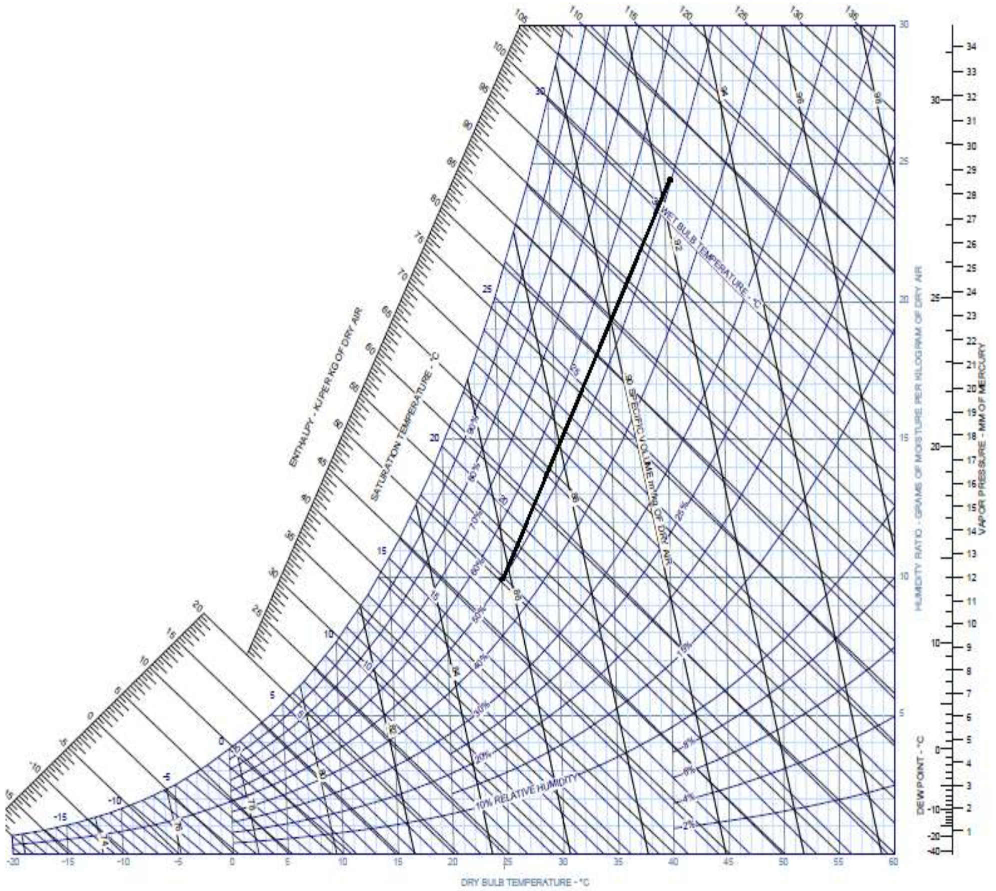

Figure 3: Psycometric chart showing sensible cooling from 42°C to 23°C while relative humidity remain constant at 50%

6. Results and Discussion

The results are as follows-

1. The split unit maintains the temperature of room up to 23°C so it reduces the temperature of air by 17°C:
The split unit takes the air from the room and circulates it back, a small portion of fresh air is taken. The unit is able to maintain temperature of 23°C into the room; this effect is almost equal to AC.

2. The COP of system is 7.
By using eqn. no. (7) we have calculated the COP as 7.

3. The total power consumption of unit is 130 W, which is quiet less than that of AC:
As the unit contains only two fans (Each of 40W) and two submersible pumps (each of 20W) its power consumption is 130W

4. It does not increase the humidity of air, the unit cools air sensibly:
There is no direct contact of supply air with water, as the air supplied through the split unit. Thus the humidity of air will not increase and will remain constant. The evaporative cooler is kept outside the room it will not be able to add the moisture.

7. Conclusion

The experimental investigation above confirmed that the split unit has demonstrated reasonable potential for use as a wetted media in evaporative cooling systems. Consequently, it creates the possibility of new sustainable engineering systems where either cooling or humidification is required. As the unit maintain the temperature 23°C and it has low cost than AC, so it will be a good replacement for AC.

8. Future Scope

For the future modifications, if the density of split unit is reduced then we can achieve even better performance. This unit is a bit bulky; if we work on the design the unit will acquire less space. Also for getting more cooling effect we can increase the thickness of cooling pads of evaporative cooler. Due to this the incoming air in evaporative cooler will reject more heat in pads; hence the water in the tank of evaporative cooler will become more cool, and if this extra cooled water is circulated in split unit it will definitely give more cooling effect.

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