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EXPERIMENATAL INVESTIGATION OF THERMAL CHARACTERISTICS ON CROSS FLOW TUBULAR HEAT EXCHANGER FOR INDIRECT EVAPORATIVE COOLING

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ABSTRACT
The demand for cooling system increases worldwide. Indirect Evaporative cooling can be used to cool air from the surface of heat exchanger without change in humidity. As there is no contact between water and air due to cross flow heat exchanger. Primary air stream is cooled by secondary air stream after evaporation of water in wetted surface of cross flow tubular heat exchanger made of PVC pipe and tested it in summer condition. By measuring humidity and DBT thermal characteristic such as cooling capacity, heat transferred per unit time, wet bulb effectiveness, COP, Dew point effectiveness is calculated.

Temperature difference between inlet temperature (from atmosphere) and outlet temperature (to room) up to 8 to 10 ºC is achieved with constant Humidity.

KEYWORDS- Tubular heat exchanger, Indirect evaporative cooling, cross flow HX.

INTRODUCTION

In an indirect evaporative cooling system, which usually has some type of heat exchanger, the air can be cooled without absolute humidity change since the product air is kept separate from evaporation process. The surface of the cooling air passages is wetted by spray water (also named recirculation water), so that water film evaporates into the cooling air and decreases the temperature of the wetted surface. The primary air flows in the alternative passages and is cooled by indirect contact with the spray water film through the separating wall of the heat exchangers. Present days, energy availability is essential for daily life and welfare all over the world. Therefore, population and growth are expected to involve a faster increase in energy consumption, despite the rise in fossil fuel prices. Taking this into account, many problems such as dependency on sources, increased cost or the environmental impact of energy use and transformation are to be faced. Thus, new legislation to ensure sustainable energy provision at an affordable price is needed. The environmental impact associated to the use of energy from conventional fossil origin, the energetic and economic dependency on non-renewable sources, lead to the necessity of reducing the energy consumption, maintaining the current targets and necessities of each activity that require the use of energy. However, not only the economic savings have to be considered in the study of the improvements in energy efficiency, whose profitability is commonly uncertain, but also the reduction in the environmental impact or in the misused of natural resources implied. In an Indirect evaporative cooler (IEC), a primary (also called 'product') air stream is cooled by simultaneous heat and mass transfer between a secondary (also called 'working') air stream and a wet wall surface. The latent heat transport, in connection with the vaporization of the liquid film, plays an important role in the heat transfer process.

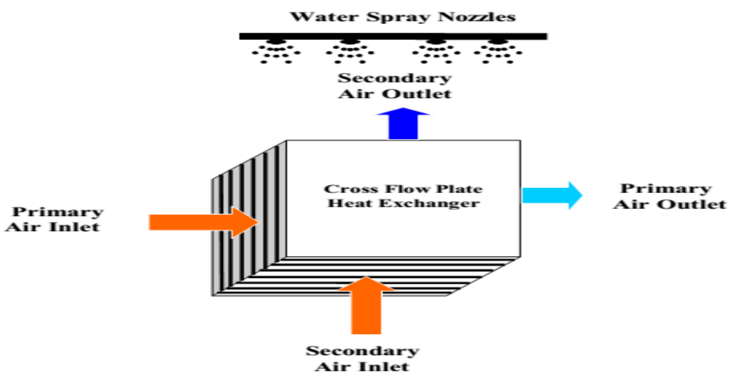

Figure0 working principle of Indirect Evaporative Cooler [8]

The Indirect Evaporative Cooling on a psychometric chart can clearly show the change in parameters such as temperature and humidity. The air is entering at higher dry-bulb temperature and leaves at lower dry-bulb temperature. But moisture content is constant that is there is no addition of moisture.

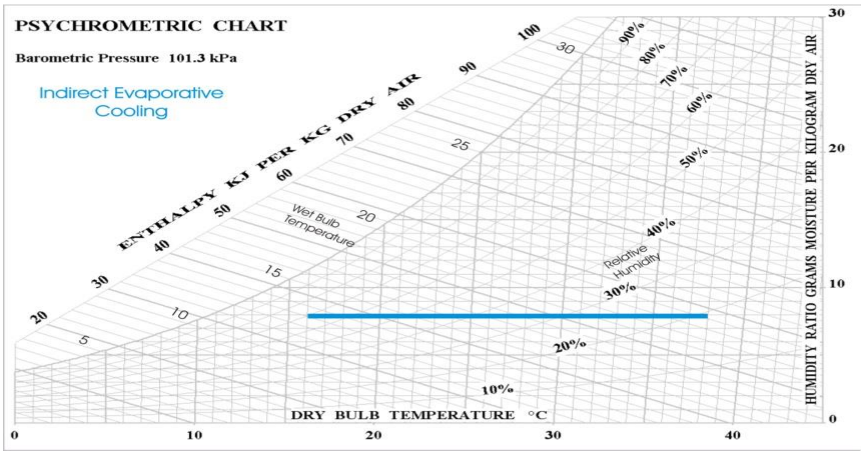

Figure 2 Psychometric Chart of Indirect Evaporative Cooler [5]

LITERATURE REVIEW

The performance of experimental two-stage indirect/direct evaporative cooling system was evaluated by Ghassem Heidarinejad et. al, in various climatic conditions of Iran. Results show that considering the variety of climatic conditions, this system has high potential to provide comfort conditions in regions where at present stand-alone direct evaporative coolers cannot provide comfort conditions. Also, in regions with higher wet bulb temperatures, this system can be used instead of mechanical vapor compression systems, so leading to decrease electrical energy consumption. Results show that average water consumption of two-stage evaporative cooling system is 55% more than direct evaporative cooling system and power consumption is 33% of mechanical vapor compression cooling systems, so this cooling system can be used in various climatic conditions as an environmentally clean and energy efficient system. [8]

The effects of air stream direction in the channels of indirect evaporative cooler(IEC) on system performance was investigated by M. Shariaty-Niassar, N. Gilani.In addition, the dependence of system performance on outdoor air temperature and relative humidity has been studied to determine the allow able conditions for proper operation of the system, with respect to thermal comfort criteria. For this; the different types of IECs were investigated using the CFD technique. Several codes were defined in MATLAB for modeling the parallel flow, counter flow and cross flow layout. The CFD program was validated against theoretical data from the literature and good agreement between the prediction and measurement was achieved. The calculated results show that when the air relative humidity was lower than 70%, the system can prepare a good indoor condition even at 50°C, and a higher performance is achieved by using the IEC with counter current configuration. The results showed that IECs can be successfully used in hot and humid climates to fulfill the indoor thermal comfort conditions. [9]

The environmental impact associated to the use of energy from conventional fossil origin, the energetic and economic dependency on non-renewable sources, lead to the necessity of reducing the energy consumption, maintaining the current targets and necessities of each activity that require the use of energy was stated by Dr.C.R.Patil, & K.G.Hirde. Evaporative cooling is a common process in nature, whose applications for cooling air are being used since the ancient years. In fact, it meets this objective with low energy consumption, being compared to the primary energy consumption of other alternatives for cooling, as it is simply based in the phenomenon of reducing the air temperature by evaporating water on it. This process can be an interesting alternative to conventional systems in these applications where not very low temperatures are needed, like the case of air-conditioning during the summer. In this paper various types of direct and indirect cooling methods are reviewed to understand the various ways to attain cooling by these methods and provide alternative. [4]

The main advantages of evaporative coolers are their low cost and high effectiveness, permitting a wide range of applications and versatility in the buildings, dwellings, commercial and industrial sectors. They can be specially applied in dry and hot climates, as the minimum cooling temperature for the air depend on it's the wet bulb temperature. The places where these systems result to be more effective are those characterized by dry and hot climates. However, evaporative cooling systems in a recovering configuration can be applied in whatever climate, as they take advantage of stuffed exhaust air from conditioned rooms, whose conditions are close to those of comfort, to cool the water used in the evaporative process.

PROBLEM STATEMENT

1. The major disadvantage of mechanical refrigeration system is that it requires a large amount of electricity for operation, which in turn affects the fossil fuels as they are required to produce electricity and these systems are not eco-friendly.
2. Refrigerants are widely used in mostly all the HVAC systems which are hazardous to the environment.
3. The direct evaporative cooling systems cause a certain degree of discomfort due to increase in the humidity of cool air after certain period.
4. IEC is a feasible alternative to conventional mechanical refrigeration systems, which would lead to realization of low (zero) carbon air conditioning served for buildings.
5. Indirect evaporative cooling systems takes advantage of evaporative cooling effects but cools without raising indoor humidity.

OBJECTIVE

1. Design new type of PVC pipes heat and mass exchanger.
2. To obtain cool air at the outlet.
3. Use of light weight and corrosion-less material.
4. Maintain constant humidity.
5. To develop eco-friendly and low operating cost air condition system.

METHODOLOGY

Indirect evaporative cooling is a method of cooling a fluid stream; usually air, by evaporating a cooling liquid; usually water, into a second air stream while transferring heat from the first air stream to the second. In principle, the structure allows the air to flows inside the tube and the exhaust air flows perpendicular to the PVC pipes over the opposite wet side of the tube. The wet side absorbs heat from the dry side by evaporating water and therefore cooling the dry side, while the water is sprinkled on the tubes. The method has certain inherent advantages compared to conventional air conditioning systems: low electricity requirements, relatively high reliability, and no use of Refrigerants.

EXPERIMENTAL SETUP

In an Indirect evaporative cooler (IEC), a primary air stream is cooled by simultaneous heat and mass transfer between a secondary air stream and a wet wall surface. The latent heat transport, in connection with the vaporization of the liquid film, plays an important role in the heat transfer process. In this experiment the dry bulb temperature and Relative humidity is measured by Hygrometer. Hygrometer is a device used to measure Relative humidity. Wet-bulb temperature, Dew point temperature, Enthalpy is calculated from psychometric chart.

To simplify calculations, psychometric properties of non-dry air are plotted on standard psychometric charts. Psychometric properties include wet-bulb temperature, dry-bulb temperature, relative humidity and enthalpy.

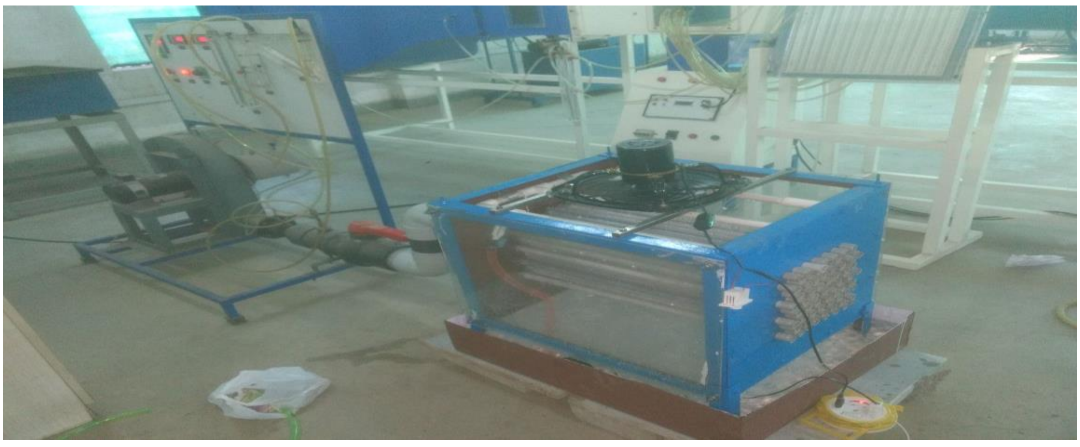

Figure 3 Working Diagram of Indirect Evaporative Cooler.

CALCULATIONS

1) Wet bulb Effectiveness: The wet bulb effectiveness is the ratio of temperature depression of the device to the wet bulb depression of the system.

$$\epsilon_{wb} = \frac{Ti - To}{Ti - Twb,i} \qquad (1)$$

2) Dew point Effectiveness: The wet bulb effectiveness is the ratio of temperature depression of the device to the dew point depression of the system.

$$\epsilon_{dp} = \frac{Ti - To}{Ti - Tdp,i} \qquad (2)$$

3) Cooling Capacity

The cooling capacity refers to the enthalpy change of the product air when travelling across the dry channels of the IEC heat exchanger. It is denoted by Q.

$$Q_{cool} = \rho_f V_{p,out}(h_i - h_o) \qquad (3)$$

$\rho_f = 1.225\ Kg/m^3$

$(h_i - h_o)$ is the difference between the Inlet and Outlet Enthalpy (KJ/kg)

$V_{p,out}$ is the volumetric flow rate of outlet air, it is expressed as

$$V_{p,out} = Flow\ area \times Outlet\ air\ velocity \qquad (4)$$

4) COP (Co-efficient of Performance)

COP is the ratio of cooling capacity of the IEC to the power consumption of the system.

$$COP = \frac{Q_{Cool}}{W} \qquad (5)$$

5) Heat Transferred per unit time(Q)

Heat Transfer Calculation by Fourier law

$$Q=kA(dT/s) \qquad (6)$$

Where,

Q = heat transferred per unit time (W) ,A = heat transfer area (m^2),k = thermal conductivity of the material (W/m.K),dT = temperature difference across the material (K)

s = material thickness (m)

RESULTS AND DISCUSSION

By obtaining the readings from observations, the wet bulb effectiveness, dew point effectiveness, cooling capacity, coefficient of performance and Conductive Heat Transfer is calculated as follows

Table 1 Result Table

Sr No	Wet bulb effectiveness (ϵ_{wb})	Dew point effectiveness (ϵ_{dp})	Cooling Capacity (Q_{cool})	Coefficient of Performance (COP)	Conductive Heat Transfer (Q)
1	116.69	80.12	0.7207	11.83	1.4135
2	83.70	57.084	0.5224	4.146	1.0019
3	71.78	45.35	0.4038	1.475	0.7586
4	59.11	40.31	0.3501	0.810	0.6441
5	51.99	37.75	0.3012	0.429	0.5367
6	36.97	25.14	0.2090	0.185	0.3757
7	48.10	33.25	0.2870	0.167	0.5012
8	43.17	32.61	0.2558	0.093	0.4473
9	36.83	25	0.2152	0.049	0.3757

Maximum wet bulb effectiveness and dew point effectiveness are 116.69% and 80.12% respectively. The minimum difference between inlet wet bulb temperature and outlet dry bulb temperature obtained is 7.9˚C . Practically there is no difference in humidity. The maximum temperature drop achieved was 8-10˚C.

Table 2 Outlet Air Flow vs Outlet Temperature Table

Sr.No	Outlet Air Flow(m3/s)	Outlet Temperature(°C)
1	52	20.1
2	88	21.9
3	120	22.5
4	151	23.2
5	197	23.8
6	236	24
7	282	24.4
8	343	24.5
9	408	24.8

Graph for the outlet air flow and outlet temperature

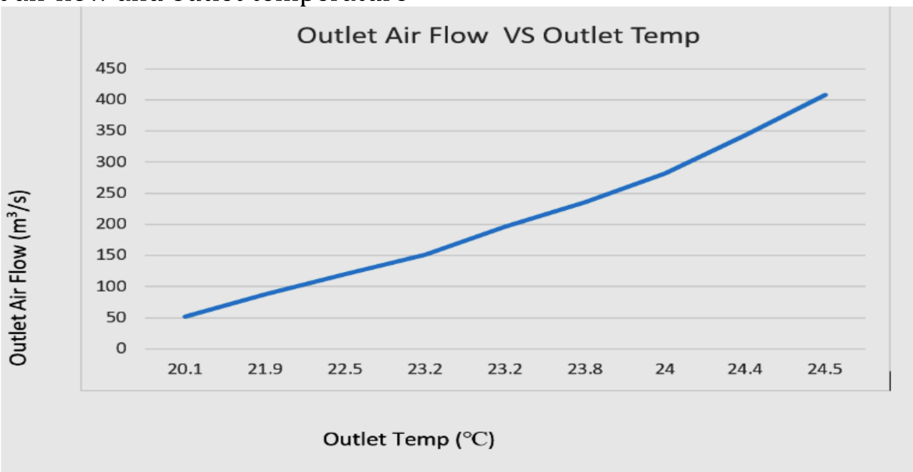

Figure 4. Graph Outlet Flow vs Outlet Temp

Above graph shows that as the flow rate increases temperature increases.

CONCLUSION

The IEC has advantages of conducting cooling of air using principle of water evaporation with no moisture being added into the air. This creates a comfortable space environment using the reserved energy in atmosphere rather than fossil fuels, fuel depended electricity, thus making it a potential alternative to the conventional mechanical vapour compression refrigeration systems.

1. It is environment friendly system.
2. It does not emit greenhouse gases.
3. It requires less water consumption.
4. According to conducted experimentation on IEC, the temperature of outlet air was reduced by 8-10˚C compared to the inlet air.
5. The humidity achieved is almost constant.
6. More effective design of heat exchanger can further improve the results.

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