Review and Design of Indirect Evaporative Cooling System

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Abstract.

Active air conditioning system consume a significant amount of electricity for cooling application, therefore it is necessary to investigate low-energy consuming cooling systems such as evaporative cooling. The objective of this paper is to give an overview of evaporative cooling as well as a design for an in-direct type evaporation cooling system. This paper describes an evaporation type passive cooling system and uses Evapcal software to design an in-direct type evaporation passive cooling system. A hospital building in Karnataka's eastern region was studied as a case study. It was observed that the in-direct type evaporation cooler system's air output temperature and relative humidity will be 25.4 ^{0}C and 53% respectively. During summer season, indirect evaporative cooling system provides comfort condition for 60% of operational hours.

Keywords. Evaporative Cooling, Evapcal, Indirect evaporative cooling

1. INTRODUCTION

The buildings uses large amount energy out of total energy consumption worldwide. Cooling accounts for large amount of energy consumption out of total building energy consumption. Existing vapour compression system uses large amount of electricity for cooling purpose. To reduce the electricity consumption for cooling, evaporation type passive cooling systems can be used to replace the existing mechanical vapour compression systems. The two main types of evaporation based cooling systems are direct type evaporation passive cooling and in-direct type evaporation passive cooling. Direct type evaporative cooling occurs when air molecules comes into direct contact with water particles, cooling the air and adding moisture to it. In an in-direct evaporative cooling process, product air passes through a dry passage while working air passes through a wet passage and the product air is cooled without addition of water particles. When compared to an active air conditioner, an evaporation kind cooling system can save up to 60% of energy [1].

Nomenclature

DB_O	Output air dry bulb temperature
DB_I	Input air dry bulb temperature
WB_I	Input air wet bulb temperature
LPH	Liters per hour

2. DESCRIPTION OF EVAPORATIVE COOLING SYSTEM

2.1 Direct evaporative cooling (DEC)

Figure 1 illustrates configuration for direct evaporation type cooling. As depicted in figure 1, in direct evaporation based cooling treatment, water from the sump is pumped by recirculating pump and sprinkled over on cooling pads through which inlet air passes and transfers heat along with water molecules. When atmospheric air passes through cooling pad, where air molecules makes direct contact with the water particles, water particles absorb the sensible heat of the air so that air get cooled and water particles vaporizes and added to the air. Figure 2 depicts a psychrometric chart, depicting the direct type evaporation based cooling method. The effectiveness of the direct type evaporative cooling method is[2]

$$\text{Effectiveness} = \frac{(DB_O - DB_I)}{(DB_I - WB_I)} \qquad (1)$$

For direct evaporative cooling effectiveness lies between 80 - 90%. Effectiveness is depends on type of cooling pad, depth of media and face velocity of air.

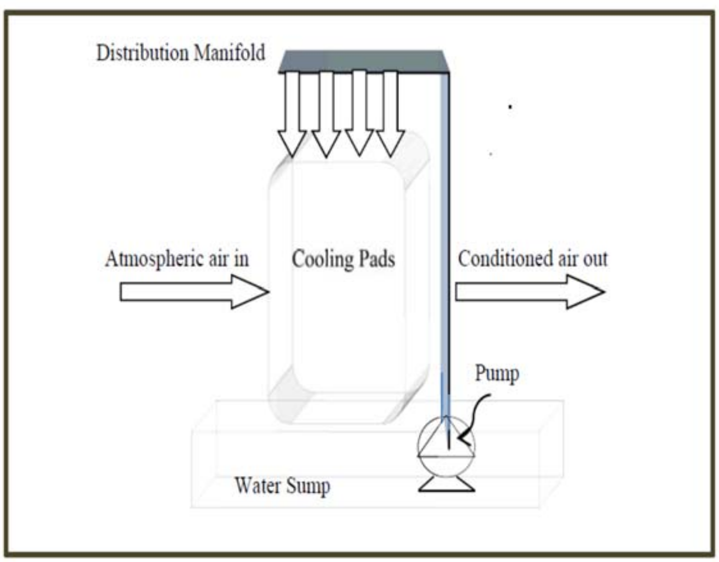

Figure1. Direct Evaporation Type Passive Cooling Method [3]

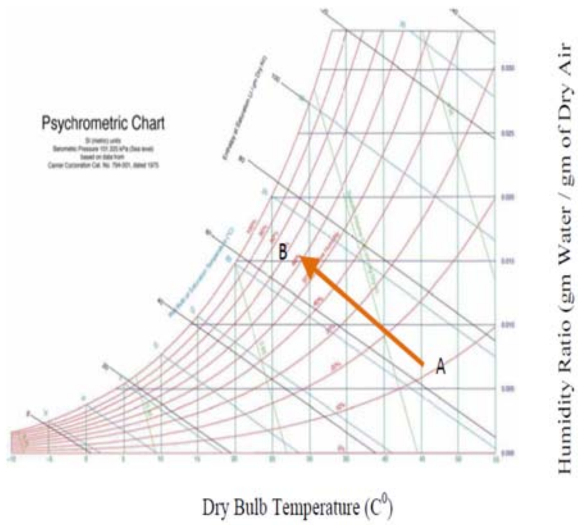

Figure 2. Direct Evaporation Type Passive Cooling method on Psychrometric Chart [4]

2.2 In-direct evaporation type cooling (IDEC)

Diagram 3 illustrates the in-direct evaporation type passive cooling process. The dry passage and the wet passage make up the indirect evaporative cooling process and a thin wall separates the two passages. In wet passage, cooling of working air is done by direct evaporation type cooling process and this cooled working air is use to cool product air flowing through dry passage. Product air is prudently cooled without addition of water particles, lowering both dry bulb temperature and wet bulb temperature. Moisture content of product air remains same during in-direct evaporation type passive cooling method. The air flow in an in-direct type evaporative passive cooling method can be in parallel, counter, or mixed flow arrangement. Figure 4 depicts the in-direct type evaporation cooling methods on a psychrometric chart. The total enthalpy of air gradually decreases in the in-direct type evaporation passive cooling method, which travels horizontally along a steady straight line on a psychrometric chart.

The effectiveness of indirect evaporative cooling (IEE) is [5],

$$IEE = \left(\frac{t_1 - t_2}{t_1 - t_3}\right) * 100 \quad (2)$$

Where, $t_1 = Supply\ air\ inlet\ dry - bulb\ temperature.$
$t_2 = Supply\ air\ outlet\ dry - bulb\ temperature.$
$t_3 = Wet\ side\ air\ inlet\ wet - bulb\ temperature.$

Effectiveness of In-direct type evaporation coolers can have up to 80%. The heat exchanger surface size, facing velocity, and degree of wetness obtained on the wet side heat exchanger surface all contribute to the efficacy of in-direct evaporation cooling. A design of an indirect evaporative cooler was created for use in data centers. In this cross flow heat exchanger was used, it was observed that simulation results were good in agreement with experimental results [6]. As a precooling unit, an in-direct evaporation cooler with intrinsic baffles may be used. [7] .The numerical and experimental work on a regenerative in-direct evaporation cooler that can provide lower wet bulb cooling was done with the Lewis factor set to unity. [8]. Heat and mass transport parameters in in-direct evaporation cooling with counter flow configurations were explored by Wan, Ren and Xing [9]. Chauhan and Rajput [10] created a combination dew point evaporative-vapour compression based air cooling system for dry and somewhat humid areas. This combination system outperforms active vapour compression devices. Antonellis et.al.[11] explored an in-direct evaporation cooling system with cross flow. and discovered that counter flow nozzles outperform parallel flow nozzles. Duan et.al. [12] carried out an experimental investigation on a counter flow regenerative cooler and discovered that the working to intake air ratio should be between 0.4 and 0.5 in order to achieve a balance of effectiveness, energy efficiency and cooling capacity. Analysis of thermal insulation material and suitability of evaporative cooling method was done [13].

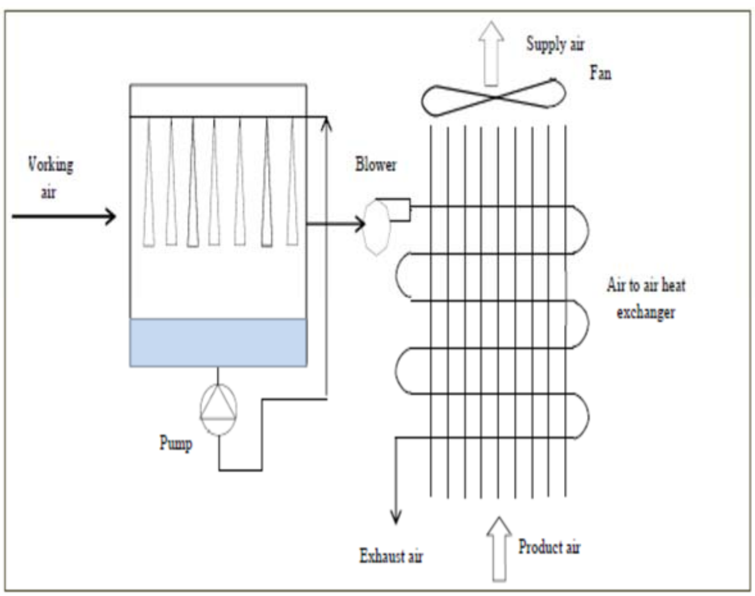

Figure 3. In-direct evaporation cooling method [2]

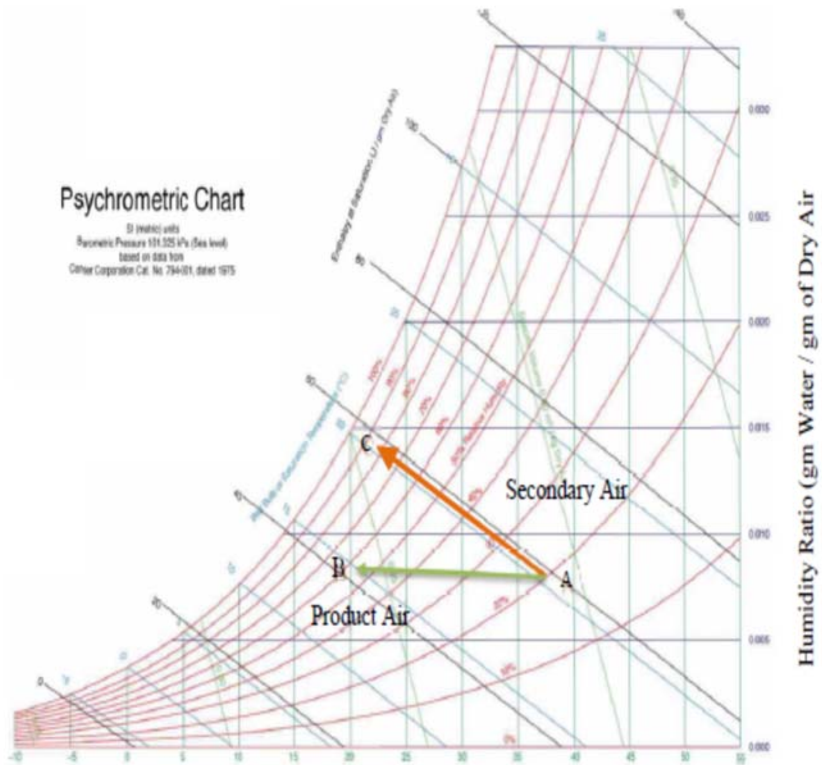

Figure 4. In-direct evaporation passive cooling method on psychrometric chart [4]

3. DESIGN OF IN-DIRECT EVAPORATION TYPE PASSIVE COOLING SYSTEM

As a study case, the Sanjivani hospital in Bellary, Karnataka, India was chosen. The overall floor area of the structure is 4143.4 m^2.The building's ground floor has a floor area of 1381.13 m^2. The wall is 3.33 meters tall. Evapcal software was used to evaluate the effectiveness of an in-direct evaporation cooling system. The total sensible and latent load of hospital's ground floor is 221.45 kW and 101.53 kW, respectively. Maximum allowable indoor temperature is 26^0C dry bulb temperature with a relative humidity 70%. After calculation by Evapcal it has been observed that, supply air temperature by indirect evaporative cooling system will be 25.4 ^{0}C, supply air relative humidity 53%, required air flow rate 733634 CFM and peak water requirement 4887 LPH. The summer season, which runs from February 1 to May 31 (2880 hours), has been taken into account in the calculations. It has been found that for 60% of operational hours, the system will provide a comfortable environment within the design range.

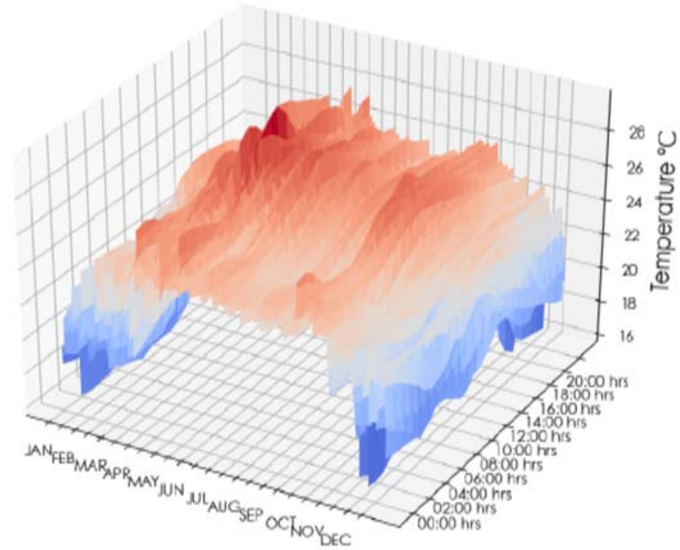

Figure 5. Dry bulb temperature inside the room

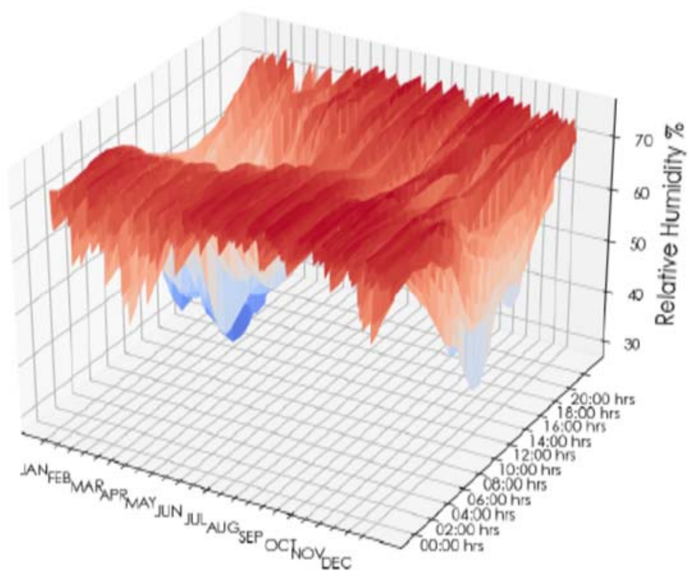

Figure 6. Relative humidity inside the room.

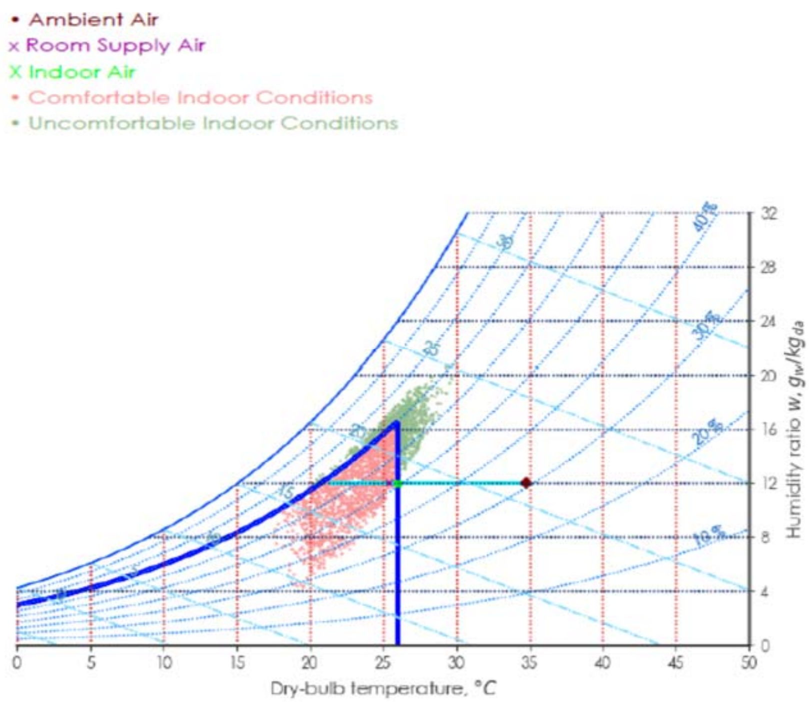

Figure7 Psychrometric comfort analysis.

4. CONCLUSION

An overview and design of an in-direct type evaporation passive cooling method was completed using Evapcal software, assuming that the indirect evaporative cooler's cooling load and efficiency remain constant throughout operational hours and that heat exchange between output air and working air is equal to heat exchange between water film and working air. With a dry bulb temperature of 25.4°C and a relative humidity of 53%, an in-direct evaporation cooling system will provide a comfortable environment for 60% of operational hours during the summer season. One of most key techniques for saving electricity in cooling is indirect evaporative cooling.

5. REFERENCES

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Biographies

Nitin S. Aher received the bachelor's degree in mechanical engineering from University of Pune in 2009, the master's degree in mechanical engineering from R.G.P.V., Bhopal in 2013, and pursuing the philosophy of doctorate degree in Mechanical engineering from University of Engineering and Management, Jaipur. He is currently working as an Assistant Professor at the Department of Mechanical Engineering, Sanjivani College of Engineering, Kopargaon, and S.P.P.U. University. His research areas include passive cooling systems, refrigeration and air conditioning and vibration analysis.