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REVIEW ARTICLE

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OPTIMIZATION OF PARAMETER FOR ADIABATIC HUMIDIFICATION IN DELHI- A REVIEW

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ABSTRACT
Humidification through cooling pads are the very common method and so many work has been done on that. However, from the previous literature review, I found that no study which carried out for the optimization of the parameter for humidification in South delhi. In this paper we optimize the parameters of humidification by using Taguchi technique .

Keyword: Humidification, Parameter of humidification, Cooling pads, Direct Evaporative cooling, Indirect Evaporative cooling, Two stage Evaporative cooling system.

1 INTRODUCTION

In this review we are going to see the research works which have been done on Evaporative cooling, indirect evaporative cooling, studies of indirect evaporative air cooler ,two-stage indirect/direct evaporative cooling system, study of evaporative cooling on the basis of direction of spray/flow (fluid use), direct evaporative cooling on basis of cooling pad material.

1.1 STUDIES OF EVAPORATIVE COOLING

A.P. Haghighi, S.S. Golshaahi and M. Abdinejad (February 2015) had Studied the Vaulted Roof Assisted Evaporative Cooling Channel for Natural Cooling. The application of evaporative cooling technique in a 1-floor stand-alone house with vaulted roof, in order to meet the required thermal needs of inhabitants and natural cooling of the interior space, has been studied in this paper. In order to investigate the capability of the system to meet thermal comfort conditions in different environmental conditions, the performance of the system has been numerically investigated for wide ranges of wind velocities, ambient air temperatures and relative humidity values. The results indicate that when the wind velocity is higher than 0.4 m/s, the air inside the building will be ventilated efficiently. In addition, as the wind velocity or the ambient air temperature increases, thermal comfort is achieved at lower values of relative humidity. The maximum allowable values for relative humidity of the ambient air to meet thermal comfort conditions are calculated based on the adaptive thermal comfort standards, and the application of the proposed system in stand-alone buildings for the centers of the provinces of Iran is investigated.

SL NO	Year of Publication	Author/s	Journal	Title of work	Brief Description
1	February 2015	A.P. Haghighi, S.S. Golshaahi	Sustainable Cities and	A Study Of Vaulted Roof Assisted	The capability of the system to meet

		and M. Abdinejad	Society	Evaporative Cooling Channel For Natural Cooling Of 1-Floor Buildings	thermal comfort conditions in different environmental conditions, the performance of the system has been numerically investigated for wide ranges of wind velocities, ambient air temperatures and relative humidity values.

1.2 Indirect Evaporative Cooling System

In August 2004 Pascal Stabat and Dominique Marchio is presented the simplified model for indirect cooling towers behavior. The model is devoted to building simulation tools and fulfils several criteria such as simplicity of parameterization, accuracy, possibility to model the equipment under various operation conditions and short computation time. On the basis of Merkel's theory, the model is described by using the Effectiveness-NTU method. The model introduces only two parameters, air-side and water-side heat-transfer coefficients which can be identified from only two rating points, data easily available in manufacturers' catalogues. Thus, the model allows one to estimate energy and water consumptions under different operating conditions such as variable wet-bulb temperatures or variable airflow rates.

Jiasheng Wu, Yanshun Yu, Lin Cao and Guoqiang Zhang (Sep 2013) had` Experimental Investigate and Analyze the Influence Factors of Lewis Number in a Cross flow Reversibly Used Cooling Tower .They reversibly used cooling towers (RUCT) are used to extract heat from atmospheric to water. In this study, the factors influencing the value of Lewis number in a RUCT are analyzed by experimental investigation. The results show that Lewis number increases with the increase of water–air flow rate ratio. When the water–air flow rate ratio is constant, the Lewis number decreases with the increase of inlet water temperature and inlet air wet-bulb temperature, increases with the increase of inlet air dry-bulb temperature and water sprinkle density. This research offers a fundamental basis for studying heat and mass transfer characteristics in a cross flow reversibly used cooling tower and practical application.

SL NO	Year of Publication	Author/s	Journal	Title of work	Brief Description
1	August 2004	Pascal Stabat, Dominique Marchio	Elsevier	Simplified Model For Indirect-Contact Evaporative Cooling - Tower Behaviour	On the basis of Merkel's theory, the model is described by using the Effectiveness-NTU method.
2	Sep 2013	Jiasheng Wu, Yanshun Yu, Lin Cao and Guoqiang Zhang	Springer	Analysis on Influence Factors of Lewis Number in a Cross flow Reversibly Used Cooling Tower	This research offers a fundamental basis for studying heat and mass transfer characteristics in a cross flow reversibly used cooling tower and practical application.

1.3Studies of Indirect Evaporative Air Cooler

P.J. Erens and A.A. Dreyer (January 1993) had discussed and modeled the indirect evaporative air coolers 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 spacing's 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.

Guo, XC (1998) had done the parametric study of an indirect evaporative air cooler. The thermal performance of an indirect evaporative air cooler is analyzed numerically. The effects of a wide variety of parameters such as the velocities of the primary and the secondary air stream, the channel width, the inlet relative humidity, and the wet ability of the plate on its-thermal performance are investigated. It is shown that a smaller channel width, a lower inlet relative humidity of the secondary air stream, a higher wet ability of the plate, and a higher velocity ratio of the secondary air to the primary air stream yield a higher effectiveness of the indirect evaporative air cooler. The results are useful for the design of an indirect evaporative air cooler.

J.F. San José Alonso, F.J. Rey Martínez and M.A. Alvarez-Guerra Plasencia (December 1998) were developed simulation model of an indirect evaporative cooler. A new heat and mass transfer model based on basic principles has been developed for thermal calculations of an indirect evaporative cooler performance. Some simplifications have been incorporated to make the model more user-friendly. It is universal and can be used to analyze different indirect evaporative cooler designs and conditions. The paper also compares results from sample calculations from several designs with data from other sources for validation. This model can be used for energy analyses as well as for system or product optimization.

Ghassem Heidarinejad and Shahab Moshari (1 April 2015) had done a novel modeling of an indirect evaporative cooling system with cross-flow configuration a new modeling of an indirect evaporative cooling system (IEC) with consideration of wall longitudinal heat conduction (LHC) and effect of spray water temperature variation along the exchanger surface in a cross-flow configuration is presented. The resultant coupled equations of heat and mass transfer are discredited using finite difference method (FDM) and solved by an iterative method. Comparing the numerical results of the presented simulation against experimental data revealed excellent agreement with them; this shows a small margin of error in the calculation (around 3%). After validation, this mathematical model is used in a two-stage system of indirect/direct evaporative cooling system, which shows that a two-stage indirect/direct evaporative cooling system in comparing to a one-stage IEC has around 50%higher wet-bulb effectiveness with the same parameters of inlet air and exchanger. Furthermore, the presented model is used for numerical simulation of a counter-flow regenerative evaporative cooler which shows around 60%higher wet-bulb effectiveness in comparing to a one-stage IEC. The numerical results of this study show applicability of the presented model for both sub-and above-wet bulb cooling applications.

SL NO	Year of Publication	Author/s	Journal	Title of work	Brief Description
1	Jan 1993	P.J. Erens and A.A. Dreyer	International Journal of Heat and Mass Transfer	Modelling Of Indirect Evaporative Air Coolers	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.
2	Feb 1998	Guo, XC	International communications in heat and mass transfer	The parametric study of an indirect evaporative air cooler.	A smaller channel width, a lower inlet relative humidity of the secondary air stream, a higher wet ability of the plate, and a higher velocity ratio of the secondary air to the primary air stream yield a higher effectiveness of the indirect evaporative air cooler.
3	Dec 1998	J.F. San José Alonso, F.J. Rey Martínez and M.A. Alvarez-Guerra Plasencia	Elsevier	Simulation Model Of An Indirect Evaporative Cooler	This model can be used for energy analyses as well as for system or product optimization.
4	1 April 2015	Ghassem Heidarinejad and Shahab Moshari	Elsevier	Novel modeling of an indirect evaporative cooling system with cross-flow configuration	A novel model for numerical simulation of a counter-flow regenerative evaporative cooler.

1. 4 Studies of Two-Stage Indirect/Direct Evaporative Cooling System

Ghassem Heidarinejad,Mojtaba Bozorgmehr and Jafar Esmaeelian (October 2009) had Experimental Investigation of Two-Stage Indirect/Direct Evaporative Cooling System in Various Climatic Conditions. Cooling performance of two-stage indirect/direct evaporative cooling system is experimentally investigated in the various simulated climatic conditions. For this purpose, a two-stage evaporative cooling experimental setup consisting of an indirect evaporative cooling stage (IEC) followed by a direct evaporative cooling stage (DEC) was designed, constructed and tested. Due to the wide variety of climatic conditions in Iran, two air simulators were provided to simulate outdoor design condition of different cities in primary and secondary air streams. Results show that under various outdoor conditions, the effectiveness of IEC stage varies over a range of 55–61% and the effectiveness of IEC/DEC unit varies over a range of 108–111%. Aspects of achieving comfort conditions and power saving have been investigated with related excess water consumption. Considering the evaporative comfort zone, this system can provide comfort condition in a vast region in Iran where direct evaporative alone is not able to provide summer comfort condition. More than 60% power saving could be obtained by this system in comparison with mechanical vapor compression systems with just 55% increase in water consumption with respect to direct evaporative cooling systems. This system can fill the gap between direct evaporative cooling systems and mechanical vapor compression systems as an energy efficient and environmentally clean alternate.

Kulkarni, R K Rajput , and Tal. Baramati were done the work on performance evaluation of two stage indirect / direct evaporative cooler with alternative shapesand cooling media in direct st age. Two stage indirect/direct evaporative cooler with wet surface plate heat exchanger type indirect stage and different shapes

and cooling media in direct stage is fabricated and tested. Rectangular, semi cylindrical and semi hexagonal shaped cooling pads made up of wood wool, rigid cellulose and aspen fiber are used as cooling media in direct stage. The performance was tested in direct cooling mode and combined cooling mode for constant secondary air flow rate of about 1 kg/s and primary air flow rate varying between 0.078 and to 1.011 kg/s. Average inlet dry bulb temperature was varying between 39 ^{0}C and 43 ^{0}C and relative humidity between 37 % and 46 % .The results show that saturation efficiency of direct evaporative cooler varies in the range of 98.3 % to 71.9 %. Overall efficiency of the unit varies in the range of 119.5 % to 74.3 % and outlet temperature of air between 27.3 ^{0}C and 32.4 ^{0}C. The cooling capacities in direct cooling mode range between 3240 and 45427 kJ/h and that for combined mode range between 4679 and 43771 kJ/h for different combinations. Such a cooler would be beneficial than stand-alone direct or indirect systems.

SL NO	Year of Publication	Author/s	Journal	Title of work	Brief Description
1	October 2009	Ghassem Heidarinejad Mojtaba Bozorgmehr and Jafar Esmaeelian	Elsevier	Experimental Investigation of Two-Stage Indirect/Direct Evaporative Cooling System in Various Climatic Conditions	More than 60% power saving could be obtained by this system in comparison with mechanical vapor compression systems with just 55% increase in water consumption with respect to direct evporative cooling systems.
2		Kulkarni, R K Rajput , and Tal. Baramati	Indian Journal	Performance evaluation of two stage indirect/direct evaporative cooler with alternative shapes and cooling media i n direct stage	The saturation efficiency of direct evaportive cooler varies in the range of 98.3 to 71.9% with secondary air flow 1kg/s and primary air flowrate varing between 0.078 to 1.011kg/s.

1.5Studies of Evaporative Cooling On Basis Of Cooling Pad Material

J.K. Jain and D.A. Hindoliya have done materials performance analysis of two new evaporative cooling pad materials. Now-a-days evaporative cooling pads are commonly made from aspen and khus fibers. These two materials along with new materials namely coconut fibers and palash fibers have been tested in a laboratory using suitably fabricated test set up. Air flow rate was kept constant. Evaporative cooling effectiveness was obtained and compared with that of aspen and khus pads. The effectiveness of pad with palash fibers was found to be 13.2% and 26.31% more than that of aspen and khus pads respectively. Whereas effectiveness of coconut fibers was found to be 8.15% more than that of khus and comparable with that of aspen pad. Khus pad offers lowest pressure drop whereas aspen pad (most commonly used) offers highest pressure drop among the four materials tested. The proposed new material (palash) offers pressure drop lower than that of the aspen pad. Because of better performance, lower

costs and easy availability of coconut and palash fibers, their use as wetted media may enhance the scope of using these materials in domestic and commercial evaporative cooling systems for sustainable development

Mahsa Barzegar, Mohammad Layeghi, Ghanbar Ebrahimi, Yahya Hamzeh, Manouchehr Khorasani(February 2012,) this study was to evaluate the performances of cellulosic pads made out of Kraft and NSSC corrugated papers in three flute sizes, experimentally. A number of experiments have been done in a wind tunnel in order to evaluate the cooling efficiency and water consumption as a function of air velocity. The tests were carried out at three levels of air velocity (1.8, 2.25, and 2.67 ms^{-1}) for three flute sizes of Kraft and NSSC corrugated papers (2.5, 3.5, and 4.5 mm). Analysis of the results indicated that cooling efficiency improves with decrease of air velocity and flute size of corrugated papers; however, water consumption increases with the increase of air velocity. The results were compared with each other and it was shown that the cellulosic pad made out of Kraft paper with 2.5 mm flute size has the highest performance (92%) at 1.8 ms^{-1} air velocity in comparison with the other cellulosic pads

Banyat Niyomvas and Bunjerd Potakarat carried the work on the efficiency of an evaporative cooler on different cooling pads. Two type of cooling pads made of a curtain fabric and a raw cotton fabric were comparatively studied. The effect of blower speeds at 725, 1015 and 1450 RPM and water flow rate of 26.9 liters per minute were investigated. The results showed that an average of the different temperature between inlet and outlet were 2.9 ^{o}C and 1.7 ^{o}C for a curtain fabric and a raw cotton fabric, respectively. Saturation efficiency of the cooling pads made of a curtain fabric was in the ranges of 46.3 to 61.3% or represents an average of 54.8%, and 29.7 to 39.2% or represents an average of 33.2% for a raw cotton fabric

Abdollah Mallia, Hamid Reza Seyfb, Mohammad Layeghic, Seyedmehdi Sharifiand, and Hamid Behraveshb (July 2011)have Investigating the performance of cellulosic evaporative cooling pads thermal performance of two types of cellulosic pads which were made from corrugated papers has been studied experimentally. Samples were tested in a sub sonic wind tunnel made from polyethylene. The pads areas are 0.5 × 0.5 m2 with 75, 100 and 150 mm thicknesses. Pressure drop, humidity variation, evaporated water and effectiveness have been investigated for several inlet air velocities. The results show that overall pressure drop and amount of evaporated water increase by increasing the inlet air velocity and thickness in both types of pads. On the other hand, effectiveness and humidity variation decrease by increasing inlet air velocity.

José Rui Camargoa, Carlos Daniel Ebinumab and José Luz Silveirab are Experimental performance of a direct evaporative cooler operating during summer in a Brazilian city, the basic principles of the evaporative cooling process for human thermal comfort, the principles of operation for the direct evaporative cooling system and the mathematical development of the equations of thermal exchanges, allowing the determination of the effectiveness of saturation. It also presents the results of experimental tests in a direct evaporative cooler that take place in the Air Conditioning Laboratory at the University of Taubaté Mechanical Engineering Department, and the experimental results are used to determinate the convective heat transfer co-efficient and to compare with the mathematical model.

NitipongSoponpongpipat and Sukum Kositchaimongkol, experimentally study therecycled high-density polyethylene and rice husk as a wetted pad in evaporative cooling system. The low cost and easy-to-find materials, for being used as wetted pad of evaporative cooling system, are necessary for agriculture. This study, thus, studied the evaporative cooling efficiency and pressure drop of recycled High-Density Polyethylene (HDPE) and rice husk as a wetted pad in evaporative cooling system. Approach: The study was done by establishing the tested wetted pad with 25.4 and 50.8 mm of thickness. The velocity air flow through wetted pad was controlled at 1, 2 and 3 m/sec respectively. In addition, the dry bulb and wet bulb temperatures of inlet air were controlled at 30.1 ± 1.0°C and 23.2 ± 1.1°C, respectively. The commercial wetted pad was also tested in order to compare results with rice husk and recycled HDPE. Results: It was found that rice husk wetted pad gave the average saturation efficiency of

55.9 %, while HDPE gave the average saturation efficiency of 29.1%. However, the pressure drop across wetted pad of rice husk and recycled HDPE was significantly higher than that of commercial wetted pad. For the effect of air velocity on saturation efficiency and pressure drop, it was found that higher air velocity decreased saturation efficiency and increased pressure drop across wetted pad. Conclusion: Finally, the rice husk has a potential as wetted pad material. However, further study about optimum point between operation cost and materials cost of using rice husk wetted pad is needed.

Franco, A.Valera, D.L.Madueño and A.Peña (2010) have done the work on influence of water and air flow on the performance of cellulose evaporative cooling pads used in Mediterraneangreenhouses. Evaporative cooling systems are a widely used technique in Mediterranean greenhouses. In this study, the cellulose evaporative cooling pads most commonly used in this region were tested in the laboratory using a new methodology in a wind tunnel to determine the water flow on the pad and air flow through it, as well as the water consumption and pressure drop caused by each pad as a function of air speed. Greater water flow increased the pressure drop, but the main effect on performance was caused by modifying the air flow through the pad. We recommend a range of air speeds through the pad of 1 to 1.5 m s^{-1} , at which the pressure drop was between 3.9 and 11.25 Pa, depending on the type of pad and the water flow applied. On the other hand, saturation efficiency ranged between 64% and 70%, while the amount of evaporated water varied between 1.8 and 2.62 kg h -1 K -1 per square meter of pad area.

Kachhwaha, S S Prabhakar, Suhas (Sept 2010) has study about theheat and mass transfer in a direct evaporative cooler. His paper presents a simple and efficient methodology to design a household desert cooler, predict performance of evaporative medium and determine pad thickness and height for achieving maximum cooling. Inputs for formulation include inlet air DBT and humidity ratio, air velocity, water temperature and flow rate, and geometrical properties of evaporative medium. A test rig was designed and fabricated to collect experimental data. Predictions of air condition at cooler outlet for given input conditions agree satisfactorily for air exit temperature (+15%) and humidity ratio (+10%). Results are useful for size selection of medium geometry required for an evaporative cooler design.

R. K. Kulkarni and S. P. S. Rajput were analyses the performance of jute fiber ropes that are used in the form of rope bank as wetted media in evaporative coolers. Widely spaced and compact arrangements of rope bank are taken into consideration. An ambient condition of 39.9°C and 32.8% RH is selected on the basis of weather data of Bhopal (2008) India particularly of weather in summer season. For the purpose of this study, the surface temperature of ropes is assumed as WBT of incoming air and theory of simultaneous heat and mass transfer is applied. Saturation efficiency, outlet temperature of air and cooling capacity are calculated for air mass flow rate of 0.9 kg/s to 0.3 kg/s. The saturation efficiency varies between 57% and 73% for widely spaced bank and between 74% and 87% for compact bank. Outlet temperature of air is determined on the basis of empirical correlation and is found to be in the range of 31.7°C-29.4°C and 29.4°C-27.4°C for widely spaced bank and compact bank respectively. The cooling capacity varies from 11243 kJ/h-26381 kJ/h and from 13384 kJ/h-33852 kJ/h for widely spaced bank and compact bank respectively. Fan power increases from 4.7 W-104.2 W and from 16.4 W-323.9 W for widely spaced and compact arrangement respectively. Variation of these parameters with mass flow of air is shown. It is seen that compact arrangement of ropes gives better performance although at the cost of high power consumption

Majumdar, N. C. Majumdar and R. N. Sharma has a new design of room cooler, working on capillary action has been described with relevant performance data, and compared with an existing type. Its cooling efficiency, volume output efficiency and overall efficiency are about 63%, 85% and 54% respectively. The necessity of periodic wetting of the cooling fabric surfaces has been avoided. Apart from its cheapness, simplicity and low running expenditure, it has been made reasonably free from risks, personal or otherwise. Detailed instructions and precautions for its proper use have also been included.

SL NO	Year of Publication	Author/s	Journal	Title of work	Brief Description
1	Dec 2011	J.K. Jain, D.A. Hindoliya	Sustainable Cities and Society	Experimental performance of new evaporative cooling pad materials	The effectiveness of pad with palash fibers was found to be 13.2% and 26.31% more than that of aspen and khus pads respectively.Whereas effectiveness of coconut fibers was found to be 8.15% more than that of khus and comparable with that of aspen pad.
2	February 2012	Mahsa Barzegar, Mohammad Layeghi, Ghanbar Ebrahimi, Yahya Hamzeh, Manouchehr Khorasani	Energy Conversion and Management	Experimental evaluation of the performances of cellulosic pads made out of Kraft and NSSC corrugated papers as evaporative media	Analysis of the results indicated that cooling efficiency improves with decrease of air velocity and flute size of corrugated papers; however, water consumption increases with the increase of air velocity
3	July 2011	Abdollah Mallia, Hamid Reza Seyfb,Mohammad Layeghic, Seyedmehdi Sharifiand, Hamid Behravesh b		**Investigating the performance of cellulosic evaporative cooling pads**	Pressure drop, humidity variation, evaporated water and effectiveness have been investigated for several inlet air velocities. overall pressure drop and amount of evaporated water increase by increasing the inlet air velocity and thickness in both types of pads
3	February 2012	,	*Energy Conversion and Management*	Experimental performance of a direct evaporative cooler operating during summer in a Brazilian city	The convective heat transfer co-efficient and to compare with the mathematical model.
4	2011	NitipongSoponpongpipat and SukumKositchaimongkol	American Journal of Applied Sciences	Recycled High-Density Polyethylene and Rice Husk as a Wetted Pad in Evaporative Cooling System	The evaporative cooling efficiency and pressure drop of recycled High-Density Polyethylene (HDPE) and rice husk as a wetted pad in evaporative cooling system.
5	2016	Franco,		Influence of Water and	The water flow on the pad and air

		A.Valera, D.L.Madueño, A.Peña, A.		Air Flow on the Performance of Cellulose Evaporative Cooling Pads Used in Mediterranean Greenhouses	flow through it, as well as the water consumption and pressure drop caused by each pad as a function of air speed. Greater water flow increased the pressure drop, but the main effect on performance was caused by modifying the air flow through the pad.
6	Sept 2010	Kachhwaha, S S Prabhakar, Suhas	CSIR	Heat And Mass Transfer Study In A Direct Evaporative Cooler	Predictions of air condition at cooler outlet for given input conditions agree satisfactorily for air exit temperature (+15%) and humidity ratio (+10%). Results are useful for size selection of medium geometry required for an evaporative cooler design.
7	2010	R. K. Kulkarni and S. P. S. Rajput	Maulana Azad National Institute of Technology	Theoretical Performance Analysis of Jute Fiber Rope Bank as Media in Evaporative Coolers	The compact arrangement of ropes gives better performance although at the cost of high power consumption
8	2010	Majumdar,N. C. Majumdar, R. N. Sharma	DEFENCE SCIENCE JOURNA	Design And Performance Of A New Room Cooler	Its cooling efficiency, volume output efficiency and overall efficiency are about 63%, 85% and 54% respectively.

1.6 Research Gap

From literature review we find different gap concerned with the topic of optimization of parameters in direct evaporative cooling.

- There is a lack of application of soft computing in the field of direct evaporative cooling.
- Rare of the researcher are repoted optimization technique in the concerned field.

1.7 Conclusions from the literature Review

We were seen in this chapter various study of evaporative cooling with comparing Saturation efficiency of pads, flow rate of water, speed of air and position of pads also described some optimization technique applied on parameters concerned with evaporative cooling.

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