PERFORMANCE ENHANCEMENT OF AIR CONDITIONING SYSTEM BY SEMI-EVAPORATIVE COOLING

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ABSTRACT

This research paper endeavors to amplify the fundamentals of operation of two varied evaporative cooling systems and defines their response to outside air through experimental analysis as developed. Through the following study, we also aim to develop a theoretical model of combined systems that lets us predict the system performance i.e., capacity consumption, energy consumption, and Human effort needed. And secondly to estimate its efficiency as compared to traditional air conditioners. Further we shall undertake to produce a thermodynamic experimental model of combined system and correlate it with conventional Air-Conditioners for different climatic conditions and examine it through an experimental setup on following points; Energy Efficiency, Cooling Capacity, Human comfort, Value for money aspect, Power consumption, Water consumption. Additionally the study aims to calculate the cooling capacity, dew point along with wet bulb effectiveness, water evaporation rate, humidity ratio, saturation efficiency, supplying back fresh air for Human comfort and effect of fan speed variation on the system.

KEYWORDS: *Evaporative Cooling, Temperature, Air Steam, DBT, WBT*

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I. INTRODUCTION

Working of combined cooling is based on air passing through a medium (PAD) where water evaporates with energy from. The atmosphere and air cools through a fan and water pump. Stale air is moved out substituted with fresh and cool air.

The cooling efficiency of evaporative cooling system is increased in following ways.

- Evaporation is increased through use of new materials.
- Combining of Direct and Indirect cooling systems.
- Use of new cooling media of different thickness and materials.

Energy efficient equipment is the need of the hour as there is ever increasing demand for reduction in energy cost, improve environmental efficiency and conforming to established standards. Evaporative cooling system fills this gap and provides desired energy efficiency [1].

The traditional direct evaporation cooling methods provide an atmosphere of concerning dormant water in continuous contact through outside environment, which produces diseases as it involves collected works along with water recirculation toward keep cooling middle soaked. Some points are- [2]

- Cooling needs are majority energy consumers in modern era.

- Mostly Air-conditioners are used in homes and commercial environments for cooling.
- Evaporative cooling offers effective and economical cooling alternate.
- Evaporative cooling methods are better suited to high dry bulb temperatures and low outdoor humidity.

Organization: This paper is prepared as: In Section II, we define the various type of evaporative cooling system for the development, In Section III we define also advantages as well as disadvantages of evaporative cooling system over conventional system. In Section IV, we explain the methodology which is used in our thesis for making more effective result. After that result discussion is describe in section V. Finally, we finish within Section VI.

2. EVAPORATIVE COOLING CLASSIFICATION

Evaporative cooling system in indirect models lower within productivity [3,4].Semi-indirect evaporative cooling is more productive as it uses permeable media thereby making it more efficient. Figure 1 represents classification of evaporative cooling system.

Figure 1: Evaporative Cooling Classification.

2.1 Evaporative Cooling in Direct Mode: In this system (Figure 2), water is injected into supply air stream with spray or liquefied medium. Water has the tendency to soak the heat from air and evaporates as a result. Thereby reducing temperature of supply air stream, dry bulb along with increasing temperatures of wet bulb as quantum of moisture present in atmosphere is increased. Figure 3 psychometric analysis of direct process.

Figure 2: Evaporative Cooling in Direct Mode.

Figure 3: Evaporative Cooling in Direct Mode (Psychrometric Chart).

2.2 Evaporative Cooling in Indirect Mode

In this system; as figure 4 represent the primarily cooled air flow through the resulting air flow which go throughout a high temperature exchanger which itself goes through water from secondary or resulting air flow[5]. The principal air flow which is cooled is distributed through a blower. One difference this system has over systems that it does not release humidity in the principal air flow thereby reducing mutually wet bulb and dry bulb temperatures. During warmer months the outside air stream can be preheated if the air from exhaust is introduced in the secondary air stream. Figure 5 represent the psychometric graph of evaporative cooling in indirect mode.

Figure 4: Evaporative Cooling in Indirect Mode.

Figure 5: Psychrometric Chart of Evaporative Cooling in Indirect Mode.

2.3 Evaporative Cooling in Direct and Indirect Mode

Figure 6 shows the evaporative cooling system in indirect mode as an intelligent system of a combination of evaporative cooling in direct mode with evaporative cooling in indirect mode where evaporative cooling in indirect mode begins cooling principal air flow followed are direct evaporative cooling. Pre cooling includes intelligent heat exchange with a result that the discharged air is much cooler and less humid. Evaporative cooler can be used as sole cooling device which is handy and easy to use. It can also be used in conjunction with normal A/C's. The point to be kept in mind is that it should be avoided as evaporative cooling humidifies and A/C's dehumidify the space[6,8]. Capacity of evaporative cooling is measured in cubic feet per minute(CFM). Overly sized evaporative cooling may result in wastage of energy, Water and also cause Humidity.

Figure 6: Evaporative Cooling in Direct and Indirect Mode.

2.4 Evaporative Cooling System in Semi Indirect

Environment comfort ability can be determined by two key factors, indoor air quality and thermal comfort.

Figure 7 shows such semi indirect evaporative cooling system made of ceramic and hollow bricks. Initially the cooling machine cools the air circulating outside the pipes by reclaiming the energy [7]. With regards to the air circulating surrounded by the pipes within contact through water flow or stream lets the occurrence of evaporative cooling.

Figure 7: Evaporative Cooling in Semi Indirect Mode.

3 AIR PSYCHOMETRIC PROPERTIES

Following discussion pertains to our effort to access the psychometric properties of Air to make our project more energy viable and efficient.

3.1. Dry Bulb Temperature (DBT): DBT is accessed by using a thermometer exposed to the air but protected from any kind of Radiation and moisture. DBT is basically temperature in absence of any moisture in the environment and is a way to access the latent heat in atmosphere. As DBT increases so does the capacity to hold moisture in atmosphere. It is expressed in degree Celsius (c) or degree Fahrenheit (°F). SI unit is Kelvin: K [8,10].

3.2. Wet Bulb Temperature (WBT): It represents the moisture content in the atmosphere. It is accessed by using a thermometer exposed to the air and its glass bulb is enveloped by a wetted wick or cloth.

3.3. Wet Bulb Depression (WBD): WBD is the contrast of wet bulb and dry bulb temperature. Wet bulb depression provides an assessment of the cooling potential evaporative cooling. When DBT is equal to WBT the atmosphere is saturated.

3.4. Dew Point Temperature (DPT): In saturated atmosphere the water vapor starts to condense out from the air. It is called dew point temperature. Above this temperature the water hangs in the air and gives an assessment of actual of actual moisture content in air. It is expressed in degree Celsius. If dew point temperature is equal to atmosphere's DBT the event is known as high relative humidity and conversely if dew point is below the air's DBT, the relative humidity is low.

3.5. Relative Humidity (RH): The comparison between the actual moisture content in air and the capacity of atmosphere to hold air at a certain temperature is known as Relative Humidity. It may also be described as the ratio of vapor pressure of moisture present to vapor pressure of moisture when air is saturated at the same temperature. [9]

3.6. Saturation Effectiveness (SE): The comparison or the ratio of initial and final dry bulb temperature to Wet Bulb depression is called saturation effectiveness

3.7. Specific Humidity (SH): The ratio of mass of water vapors to the mass of dry air present in moist air is called Specific Humidity. It is defined as mass of water vapors per kg of dry air.

3.8. Sensible Heat (SH): The Heat required a rise in temperature of air while keeping phase constant. It is followed by a rise in temperature.

3.9. Latent Heat (LH): The Quantum of heat required to change phase while keeping temperature constant is known as Latent Heat.

3.10. Sensible Heat Factor (SHF): It is the relation of sensible heat transferred to the total transferred heat during any procedure is called sensible Heat Factor.

$$SHF = Q_s / (Q_s + Q_L)$$

3.11. Fresh Air Ratio (FAR): It is the relation of whole clean air with the total air supplied to the closed breathing space, total fresh air is the addition of fresh air supplied and air re-circulated in closed space.

3.12. By Pass Factor (BPF): The air passing through cooling coil represented by ADP where as M and S are entry and exit point conditions respectively. Then the sidestep aspect of coil is defined as the ratio of air which does not come in direct contact with coil surface to the total air quantity passing through the coil.

Represented As following

$$\text{BPF} = \frac{(T_s - T_{\text{ADP}})}{(T_m - T_{\text{ADP}})} = \frac{(\omega_s - \omega_{\text{ADP}})}{(\omega_m - \omega_{\text{ADP}})} = \frac{(h_s - h_{\text{ADP}})}{(h_m - h_{\text{ADP}})}$$

3.13. Comparison of Normal Vapor Compression Based Air Conditioning System to Evaporative Cooling System and its Advantages [11]

- Hardware and installation cost of Evaporative cooling system is Less.
- Energy efficient with up to 75% lesser operational cost.
- Less maintenance cost.
- Evaporative cooling system ensures better Ventilation.
- It has a very rate of Air flow
- No undue passing or intrusion of outside air.
- No harmful chemicals used during process; therefore more environments friendly.

3.14. Drawback of Evaporative Cooling System Over the Conventional Cooling System

- Evaporative cooling system is not suitable for high humidity areas
- High Noise levels due to high rate of air circulation.
- Less control of humidity and temperature.
- Produces active micro organisms

3.15. Restrictions

- It has a continuous requirement of dry outside air [12]
- Less intelligent cooling as it shall blow warm and humid air during summer season.
- Stale smell produced from the pads due continuous presence of moisture in humid climates.
- More requirement of water in comparison to other system.

3.16. Hypothesis

- The mass stream pace of air in ordinary framework is taken as 0.28 Kg/s.
- Inside structure condition is taken as 25°C DBT and half ϕ .
- A dew point evaporative cooler,; Wet Bulb Adequacy (WBA) is taken as 1 independent of water [13].
- Cooling coil; bypass or sidestep factor is taken as 0.2.
- Cooling coil Apparatus Dew Point (ADP) is in use as 2°C for the estimation for proposed framework and regular framework.
- The electric force for fan and flowing siphon if there should arise an occurrence of evaporative cooler dew point is in use as 300 W.

4. METHODOLOGY

The SIEC (Semi Indirect Evaporative Cooler) is built with two different air flows. Primary inlet is used for cooling and secondary inlet is used for go back air flow along with it is in direct and continuous contact with water. Water and returning air flow pressure constantly circulates for enhanced Results.

- Indry as well as hot climatic conditions a thermodynamic analysis of combined structure has to be undertaken.
- Experimental setup is to be drawn for the combined system.
- Analysis of theoretical and experimental data is to be done comparing two structures on the basis of comfort air power consumption effectiveness.
- There is an enhanced cooling effect by way of twin cooling process. The Heat transferred between air allows (supply and return) and evaporation process stuck among the air supply along with outside wall. Following is the mechanism for such process
- Transfer of heat and mass through return air flow.
- Permeability and heat transfer through solid walls enabling spread of mass.
- Evaporation or condensation in air flow.
- Mass along with Heat transfer in air flow supply.

The characteristics put jointly achieve the aim of optimization of output and effectiveness by way of mass and heat transfer, enhancing cooling effect. Bottom on porosity of the wall of cooler, which divide the two air ways, enables more or less aqua dispersion towards air flow from external pores. The water vapour pressure within the supplied air is the dominant aspects within this mass convey procedure. Thus duly called Semi indirect evaporative cooler SIEC represent in Figure 8.

Figure 9 shows Refrigeration; The Removal of high temperature from the breathing space to exist cooled and maintaining temperatures lower than surroundings is known as the process of Refrigeration. This mechanism takes out heat from a space having lesser temperature to a space having with higher temperatures. Vapour Compression Refrigeration System (VCRS) is most effective for the commercial and household use because of the high value of COP and low maintenance cost in comparison to other types of Refrigeration. Restriction of the usage of water in cooling system has led to efforts to find alternate cooling methods. Figure 8; represents an experimental study of using a VCRS for cooling a steam power plant condenser.

Evaporative air cooler is the most economical and commonly used device. In a slight modification of to our model, ceramic material tube is used. Water is introduced inside the tube and due to its permeability water comes out on the outer surface of the tube. When air passes through it, the air gets cooled represent as in Figure 9.

Figure 8: VCRS with Condenser Cooling.

Figure 9: VCRS with Evaporative Cooling.

4. EXPERIMENTAL SETUP

Following experimental setup could be prepared for testing different cooling pads made of different materials; Eg. Banana, Sugarcane, Coconut, Khus fibres and Honey comb paper cooling pad.

Figure 10 Depiction of the cooling cushions; the external spreads for the cooling cushions were made utilizing a mellow steel wire work as cuboids of dimensions are 0.30 m * 0.15 m * 0.05 m.

These cuboids melded bundles were then loaded up with precisely 100g of every one of the cooling media material to be specific (as Figure 10) Honeycomb paper. This was done to guarantee same thickness and subsequently uniform attributes of all cooling cushions. Here we use Honeycomb Pad. A Ceramic pipe was too used for ingestion system and drains, although they do not seems to have been as common as lead pipes. Wood pipes were used for drains and intake systems. Here, we are showing in Figure 11; ceramic pipes which are using for evaporative cooler. In this setup, we used the various parameters with fixed range intended for the evaluation of our system that is evaporative cooling as shown in table 1.

Figure 10: Honey Comb.

Figure 11: Ceramic Pipes Used in Experimental Set Up.

Table 1: Range of Parameter

Sr.No.	Parameter	Range
1	Ambient temperature $T_o(^{\circ}\text{C})$	$30^{\circ}\text{C} - 46^{\circ}\text{C}$
2	Specific humidity $\omega_o(\text{gm/kg})$	$6\text{gm/kg} - 22\text{gm/kg}$
3	ADP	2°C
4	COP of VCR system	3
5	Pump and fan power	300W
6	Coil bypass factor (X)	0.2
7	Wet bulb effectiveness ϵ_{wb}	1
8	Mass flow rate of air $m_a(\text{kg/s})$	0.28

5. RESULT DISCUSSIONS

Past works have been created on cooling towers just as on ordinary indirect frameworks working in various atmosphere conditions, which have additionally expressed the investigation of the warm viability identified with the adiabatic immersion temperature. The outcomes got set up that for comparable open air cools the estimations of the warm adequacy are comparable.

Figure 12 shows In any case; the presentation of the ceramic evaporative frameworks is somewhat lower because of their reliance on the water course through the permeable surface, which relies upon the porosity and fume pressure, subsequently not being helpless of being controlled.

We have to discuss about economy within cooling load in terms of month wise variation in enhance semi-evaporative cooling with ceramic pipe as compare to the conventional system in figure 12 as well as discuss within cooling load in terms of month wise variation in tabular form in Table 2 and Table 3 with respect to various different parameters.

Variation of load of cooling on cooling coil w. r. t. various different parameters is explained in the table 4 as monthly wise. Variation of load of cooling on cooling coil w. r. t. humidifying within the enhance semi – evaporative cooling system as per the given parameter in our experimental set up (Figure 13).

Distinction of mass stream velocity of air w. r. t. months in the enhance semi–evaporative cooling system as per the given parameter in our proposed system as well as cooling load distinction on cooling coil toward months within the enhance semi–evaporative cooling system as per the given parameter in our proposed system in Figure 14 and Figure 15 respectively.

Figure 12: Air Conditioning System by Semi–Evaporative Cooling as Compared to the Conventional System in Terms of Variation of Saving Load with Respect to Months.

Table 2: Economy within Cooling Load in Terms of Month Wise Variation

S. No	Outside R.H (%)	Outside DBT (°C)	Month
1	25	34 (°C)	March
2	26	38 (°C)	April
3	16	43 (°C)	May
4	39	39 (°C)	June

Table 3: Tabular form Variation of Saving in Cooling Load

S. No	Tci ((°C)	Saving in Qci (%)	Tcii (°C)	Qci (kj/s)	Qcii (kj/s)	Mai (kg / s)	Qsr	Maii	Months
1	19	63.20	2.1	1.50	4.08	0.36	0.83	0.130	March
2	19	28.143	2.1	3.60	5.01	0.36	0.71	0.130	April
3	19	26.67	2.1	3.71	5.06	0.37	0.69	0.130	May
4	19	-53.21	2.1	10.70	6.99	0.40	0.51	0.130	June

Table 4: Tabular form Variation of Cooling Load on the Cooling Coil

S. No	Tci ((°C))	Qci (kj / s)	Qsr (Kj / s)	Efficiency (%)	Mai (Kg / s)	(X)	Months
1	19	0.525	0.79	71	0.13	0.2	March
2	19	1.350	0.79	71	0.14	0.2	April
3	19	1.474	0.79	71	0.15	0.2	May
4	19	4.023	0.79	71	0.16	0.2	June

Figure 13: Air Conditioning System by Semi-Evaporative Cooling as Compared to the Conventional System in Terms of Variation of Cooling Load with Respect to Humidifying.

Figure 14: Air Conditioning System by Semi – Evaporative Cooling As Compared to the Conventional System in Terms of Variation of Mass Flow Rate of Air W.R.T. Months.

Figure 15: Air Conditioning System by Semi-Evaporative Cooling as Compared to the Conventional System in Terms of Variation of Cooling Load on the Cooling Coil W.R.T. Months.

6. CONCLUSIONS

- High temperature of air and low relative humidity supplied results in evaporation from the ceramic pipes surface.
- Relative humidity and high temperature of the air provide results in thus condensation and dehumidification appears on the external flat surface of pipes and adds the latent along with rational heat.
- The analysis of four characteristic like different air, water and three relative humidity levels of the supply air conducted.
- Sensible and latent heat recovery with various factors like air flow, relative humidity levels was conducted.5. The evaluation of the effects of three system parameters like speed of air, inlet water temperature and the air dry bulb temperature on cooling performance was conducted.
- Keeping all variables constant the different parameters were evaluated.
- The results also demonstrate that the inner evaporative cooler have content with elevated humidity of the supply air as compared towards direct evaporative cooler which provides high humidity levels inside cold storage anywhere close in the direction of saturation humidity is mandatory.
- Air's dry bulb temperature closing on Dew point temperature indicates high level of relative humidity.
- Conversely if dew point is below air's dry bulb temperature it indicates low level of Relative humidity.
- The enhancement of performance of the system can be achieved by optimising different operational parameters like process air and feed water mass stream velocity along with use of different honey comb pad dimensions.

REFERENCES

1. Martín, R. Herrero. "Characterization of a semi-indirect evaporative cooler." *Applied Thermal Engineering* 29.10 (2009): 21132117.
2. A. Fouda a, Z. Melikyan. A simplified model for analysis of heat and mass transfer in a direct evaporative cooler. *Applied Thermal Engineering* 2011; 31:932936.
3. Kumar, V. Ashok, and N. Sathishkumar. "Effect of fin geometry for various tubes shape using CFD simulation on multi-channel heat exchanger in mobile air conditioning (MAC)." *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)* 8 (2018): 2632.
4. ChenguangSheng, A.G. AgwuNnanna. Empirical correlation of cooling efficiency and transport phenomena of direct evaporative cooler. *Applied Thermal Engineering* 2012; 40:4855.
5. Benziger, B., P. Anu Nair, and P. Balakrishnan. "Review paper on thermoelectric airconditioner using peltier modules." *IJME* 4.
6. AbdollahMalli, Hamid Reza Seyf, Mohammad Layeghi, SeyedmehdiSharifian, Hamid Behraves. Investigating the performance of cellulosic evaporative cooling pads. *Energy and Buildings* 2011; 52:25982603.
7. J.M. Wua, X. Huang, H. Zhang. Theoretical analysis on heat and mass transfer in a direct evaporative cooler. *Applied Thermal Engineering* 2009; 29:980984.
8. Priya, S. Shanmuga, PriyadarshiniBalachandar, and SanoberWadhwania. "Comparison of liquid desiccants for air cooling systems using wetted wall column." *International Journal of Mechanical and Production Engineering Research and Development* 9.2 (2019): 677684.
9. Y.J. Dai, K. Sumathy. Theoretical study on a cross-flow direct evaporative cooler using honeycomb paper as packing material.

Applied Thermal Engineering 2002; 22:14171430.

10. Jose RuiCamargoa, Carlos Daniel Ebinumab, Jose Luz Silveira. Experimental performance of a direct evaporative cooler operating during summer in a Brazilian city. *International journal of refrigeration* 2005; 28:11241132.
11. J.M. Wu, X. Huang b, H. Zhang. Numerical investigation on the heat and mass transfer in a direct evaporative cooler. *Applied Thermal Engineering* 2009; 29:195201.
12. T DHAKULKAR, K. A. P. I. S. H., M. R. Dharme, and K. R. Gawande. "An experimental analysis of direct evaporative cooler by varying materials of cooling pad." *International Journal of Mechanical & Production Engineering Research & Development* 7 (2017): 585590.
13. R.K.Kulkarni, S.P.S.Rajput. Comparative performance of evaporating cooling pads of alternative materials. *International journal of advanced engineering science and technology* 2008; 10:239244.
14. Sheng C, Nnanna A. Empirical correlation of cooling efficiency and transport phenomena of direct evaporative cooler. *Appl Thermal Eng* 2012; 40:48–55.
15. Hasan Ala. indirect evaporative cooling of air to a sub-wet bulb temperature. *Appl Thermal Eng* 2010; 30:2460.
16. ElDessoukyH. T. A., AlHaddad A. A., Juwayhel F. I. Thermal and hydraulic performance of a modified twostage evaporative cooler", *Renewable Energy*, 1996, 7(2).
17. Peterson JL. An effective model for indirect evaporative coolers. *ASHRAE Trans* 1993; Part II:392–9.