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Experimental Performance of Different Evaporative Cooling Pad Material of Direct Evaporative Cooler in Hot and Dry Region

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Abstract—**An experimental performance of evaporative cooling pads of different materials based on weather data of vidharbha, India has been carried out. Saturation efficiency and cooling capacity of thickness 4 inch cooling pad materials were measured. Effect of air and water flow rate on saturation efficiency and cooling capacity has been investigated for different cooling pad materials like cellulose, khus-grass, and wood-wool material. Saturation efficiency and cooling capacity have been calculated for flow rates of air between 0.25 to 0.45 m^3/s and for water flow rate of 60 to 100 cc/hr. Saturation efficiency and cooling capacity variation with water and air flow rate is plotted for different materials of the pads. It has been observed that cellulose material gives highest saturation efficiency of about 92.8% while Khus-Grass material gives lowest saturation efficiency of about 40.13%. The cooling capacity increases with air flow rate and is obtained between 1.1 to 6.72 kW for different materials.**

Keywords— Evaporative cooling; Cooling capacity; Saturation efficiency; Cellulose; wood-wool; khus-Grass;

I. INTRODUCTION

Depleting energy resources and increasing environmental pollution have shifted the attention of all researchers all over the world to alternative air conditioning systems. Summer air conditioning systems capable of maintaining exactly the required conditions in the conditioned space are expensive to own and operate. Sometimes, partially effective systems may yield the best results in terms of comfort and cost. Evaporative air conditioning systems are inexpensive and offer an attractive alternative to the conventional summer air conditioning systems in places, which are hot and dry. Evaporative air conditioning systems also find applications in hot industrial environments where the use of conventional air conditioning systems becomes prohibitively expensive.

Evaporative cooling system is based on the principle that when moist but unsaturated air comes in contact with a wetted surface whose temperature is higher than the dew point temperature of air, some water from the wetted surface evaporates into air. The latent heat of evaporation is taken from water, air or both of them. In this process, the air loses sensible heat but gains latent heat due to transfer of water vapour. Thus the air gets cooled and humidified. The cooled and humidified air can be used for providing thermal comfort.

II. EVAPORATIVE COOLING SYSTEM TYPES

A. *Direct Evaporative Cooling (open circuit)*

Direct evaporative cooling introduces water directly into the supply airstream (usually with a spray or some sort of wetted media). As the water absorbs heat from the air, it evaporates and cools the air.In direct evaporative cooling the dry bulb temperature is lowered but the wet bulb temperature remains unchanged. In operation, a blower pulls air through a permeable, water-soaked pad. As the air passes through the pad, it is filtered, cooled, and humidified. A recirculation pump keeps the media (pad of woven fibers or corrugated paper) wet, while air flows through the pad. To ensure that the entire media is wet; more water is usually pumped than can be evaporated and excess water drains from the bottom into a sump. An automatic refill system replaces the evaporated water. The efficiency of direct cooling depends on the pad media. A good quality rigid cellulose pad can provide up to 90% efficiency while the loose aspen wood fiber pad shall result in 50 to 60% contact efficiencies.

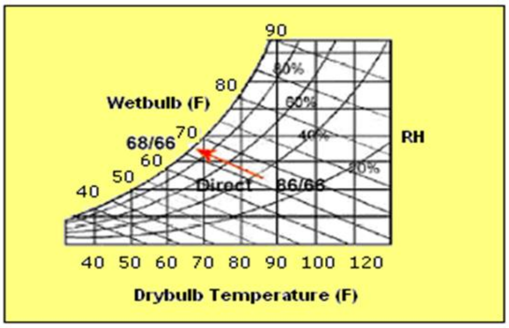

Fig. 1. Cooling path for direct evaporative cooler

B. Indirect Evaporative Cooling (closed circuit)

Indirect evaporative cooling lowers the temperature of air via some type of heat exchanger arrangement, in which a secondary airstream is cooled by water and which in turn cools the primary airstream. The cooled air never comes in direct contact with water or environment. In indirect evaporative cooling system both the dry bulb and wet bulb temperatures are reduced. Indirect evaporative coolers do not add humidity to the air, but cost more than direct coolers and operate at a lower efficiency. The efficiency of indirect cooling is in the range of 60-70%.

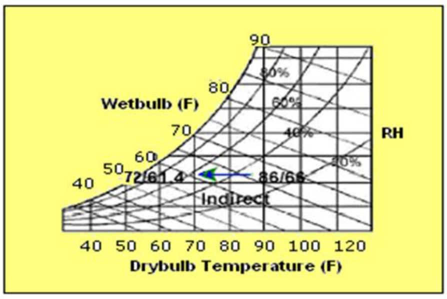

Fig. 2. Cooling path for indirect evaporative cooler

C. Two-stage Indirect/direct Evaporative Cooling

Two stage evaporative coolers combine indirect with direct evaporative cooling. This is accomplished by passing air inside a heat exchanger that is cooled by evaporation on the outside. In the second stage, the pre-cooled air passes through a water-soaked pad and picks up humidity as it cools. Because the air supply to the second stage evaporator is pre-cooled, less humidity is added to the air, whose affinity for moisture is directly related to temperature. The two-stage evaporative cooling provides air that is cooler than either a direct or indirect single-stage system can provide individually. In many cases, these two-stage systems provide better comfort than a compressor-based system, because they maintain a more favourable indoor humidity range. An advanced two-stage evaporative cooler uses 100 percent outdoor air and a variable speed blower to circulate cool air. Two-stage evaporative coolers can reduce energy consumption by 60 to 75 percent over conventional air conditioning systems, according to the American Society of Heating and Engineers (ASHRAE). Yet this relative improvement depends on location and application

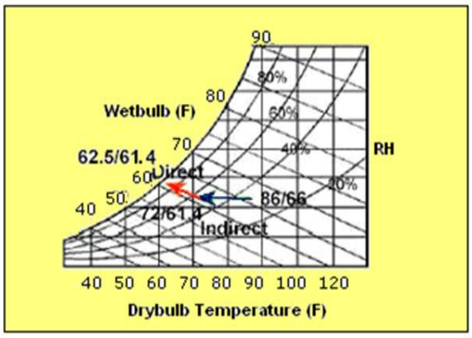

Fig. 3. Cooling path for multistage (indirect-direct) evaporative cooler

III. EXPERIMENTAL SETUP

The direct evaporative cooling unit that is used for this study consists mainly of an exhaust fan at the end of the unit and a re-circulating pump to drip water on the upper side of the pad. As shown in Fig. 1, the air enters the pad in a horizontal configuration. The evaporative cooler is made of Galvanized iron sheet; its height, length, and width are 61cm, 61cm,and 46cm respectively, and it has a sump with dimensions and it has sump with dimensions ,cross section are 61cm×46cm and height 16cm. A cellulose pad, khus-grass, wood-wool is used as the packing material with a length of 56 cm, width of 56 cm and thickness of 75 cm, as shown in Fig.1. The packing is made of packing material with a specific surface area of 100 m^2/m^3 and an equivalent diameter of 0.0093 cm.

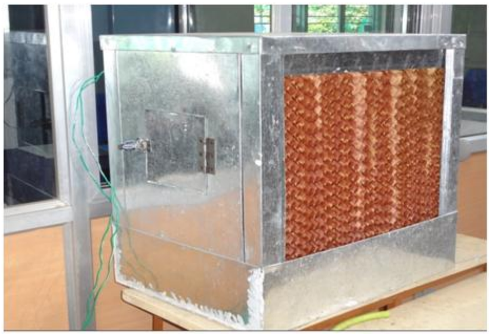

Fig4. Photograph of Direct Evaporator cooler

A. Calculation of saturation efficiency cooling capacity

- Calculate the saturation efficiency and cooling capacity of evaporator cooler.

Saturation efficiency is given by

$$\in = \frac{T_1 - T_2}{T_1 - T_{wb}}$$

- Cooling capacity is given by

$$Q_C = m_a \, Cp_a (T_1 - T_2)$$

Where,

Cp_a = Specific heat of air, J/Kg k
m_a = Air mass flow rate, kg/sec
T_1= Evaporative outdoor dry bulb temperature ℃
T_2= Evaporative indoor dry bulb temperature ℃
T ωb = Evaporative indoor wet bulb temperature℃
$\in$ = Evaporative saturation efficiency, %
Q_C = Cooling capacity, KW

B. Instrument used

Sling psychrometer, anemometer and rota meter has been used for measurement of DBT, WBT, and air and water flow rate.

TABLE I: COOLING CAPACITY AT VARIOUS AIR FLOW RATE (water flow rate constant)

water flow rate (cc/hr)	Air flow rate (m^3/s)	cellu lose	Wood -wool	Khus-grass
60	0.25	3.29	1.6	1.12
	0.35	4.86	3.01	1.96
	0.45	5.79	4.09	2.26

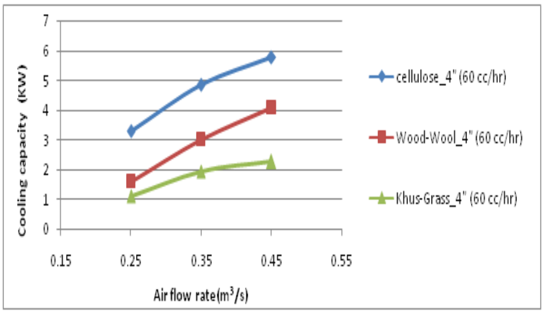

Fig.5. Cooling capacity vs Air Flow Rate

water flow rate (cc/hr)	Air flow rate (m^3/s)	cellu lose	Wood -wool	Khus-grass
80	0.25	3.7	2.071	1.345
	0.35	5.2	3.06	1.881
	0.45	6.38	4.1	3

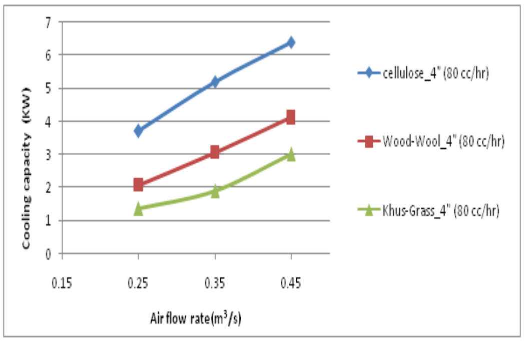

Fig.6. Cooling capacity vs Air Flow Rate

water flow rate (cc/hr)	Air flow rate(m^3/s)	cellu lose	Wood-wool	Khus-grass
100	0.25	3.62 1	1.52	1.24
	0.35	5.02	2.54	1.76
	0.45	6.72	3.07	2.74

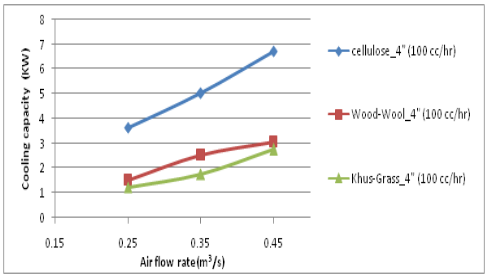

Fig.7. Cooling capacity vs Air Flow Rate

TABLE II: SATURATION EFFICIENCY AT VARIOUS WATER FLOW RATE (Air flow rate constant)

Air flow rate(m^3/s)	Water flow rate (cc/hr)	Cellu lose	Wood-Wool	Khus-grass
0.25	60	84.5	41.011	26.31
	80	83.94	36.86	31.78
	100	89.28	28.57	29.81

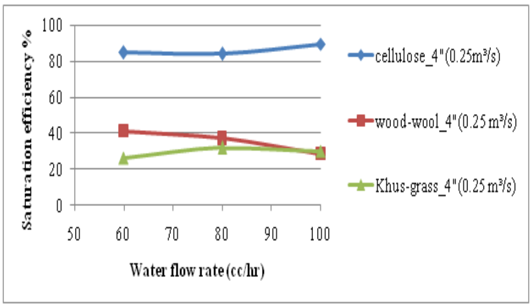

Fig. 8. Saturation Efficiency vs Water Flow Rate

Air flow rate(m^3/s)	Water flow rate (cc/hr)	Cell ulose	Wood-Wool	Khus-grass
0.35	60	76.5 6	38.7	34.24
	80	87	39.48	31.11
	100	88.5 7	33.9	25.71

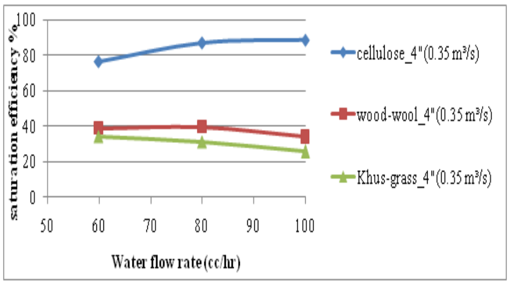

Fig. 9. Saturation Efficiency vs Water Flow Rate

Air flow rate (m^3/s)	Water flow rate (cc/hr)	Cellulose	Wood-Wool	Khus-grass
0.45	60	83.94	44.44	28.12
	80	92.48	44.44	40.13
	100	92.8	38.7	30.61

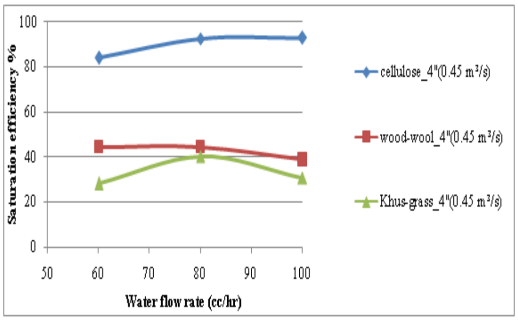

Fig. 10. Saturation Efficiency vs Water Flow Rate

IV. CONCLUSION

Based on experimental performance of different evaporative cooling pad material it has been found that there exist water flow rate for which saturation efficiency is maximum. For a fixed water flow rate with variation in air flow rate saturation efficiency is almost constant. However with increase in air flow rate cooling capacity increases. It has been observed that cellulose material of thickness 4" gives highest saturation efficiency of about 92.8% while khus-grass material gives lowest saturation efficiency of about 40.13%. With higher wetted surface area gives higher saturation efficiency. The outlet temperature of air is varying between 24°C and 29 °C. The cooling capacity increases with air flow rate and is obtained between 1.1to 6.72 kW for different materials.

V. REFERANCES

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