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Performance Evaluation Of A Direct Evaporative Cooler For Pune Region Summer Conditions

M.M.Kulkarni[1], Dr.K.N.VijayKumar[2], M.T.Kusalkar[3], R.D.Raut [4], N.R.Tiwari[5]

[1,3,4,5]SKN College of Engineering, Vadgaon, Pune, University of Pune, India 411041

[2]D.J.Sanghavi College of Engineering, Vile-Parle, Mumbai, University of Mumbai, India 400056

Abstract

The paper presents performance evaluation of direct evaporative cooler using experimental investigation for summer climatic conditions of Pune city. Various performance parameters like location of cooler, ventilation condition, speed of air effectiveness, cooling capacity, cooler outlet temperature, indoor room average temperature and humidity were evaluated.

It is observed that performance of evaporative cooler is better if it is located outside room as compared to inside location. Temperature reduction of 2^0C to 3^0C & humidity reduction of 10% is achieved which is beneficial from comfort condition point of view. Secondly, when ventilation is provided with 100% fresh air, humidity of room is maintained within 40% to 60% that is within favorable limits against closed door condition while RH is found to be on higher side i.e. more than 60% which is undesirable. Lower air speed has delivered comfort conditions as compared to high speeds. Temperature maintained during day varies from 21^0C to 24 ^{0}C & inside room RH is 45 % to 55%.Cooling capacity varied from 1.088 KW to 3.79 KW & effectiveness varied from 0.55 to 0.88.

Thus, it is recommended that Direct Evaporative Cooler can replace mechanical refrigeration system typically air conditioners & provide huge scope for energy saving for Pune summer conditions.

Keywords:-Direct Evaporative Cooling, Saturation efficiency, Cooling Capacity, Solar Radiation

1. Introduction:

In today's era of increased energy consumption, it is significant to design systems that can operate at lower power input without compromising basic purpose of serving. Energy consumption in space cooling is contributing largely due to use of increased air conditioning. Present air conditioning market is dominated by window & split air conditioners. However, these devices consume more power. It is estimated that by 2025, energy demand by sole air conditioning will increase to 7.5 million GW. An energy efficient option is available in the form of evaporative cooling. Even though, it is used from ancient time, its use has become significant in present energy crisis time.

This paper is dedicated to detailed investigation of feasibility, performance, effectiveness & cooling capacity of DEC to investigate scope and potential to replace A.C. for Pune summer conditions. Evaporative cooling is fast, simple, lower power consumption, environmental friendly, silent feasible & green technique of space cooling. Pune is multiclimate city with temperature varying from 10^0C to 42^0C & RH ranging from 20% to 85% within year. Use of evaporative cooling is beneficial under conditions when air is hot and dry. Pune summer conditions encounters temperature 25^0C to 40^0 C & RH 20 % to 50%. These conditions are well suitable for DEC of Pune i.e March, April May, & June.

2. Evaporative cooling:

When hot & dry ambient air comes in contact with water, on some surface, water evaporates. The heat required for evaporation of water is absorbed from air and as a result air get cooled & humidified. When air and water are mixed physically, heat & mass transfer takes place. Figure 1 shows arrangement of typical EC and figure 2 represents the process on psychrometric chart. The essential components of DEC are pad materials, fan, motor & pump .Various pad materials like aspen, khus, jute, Celdek paper are in common use . Pump capacities typically vary from 1200 LPH to 2800 LPH with of 20 W to 45 W. Fan used backward blade metal, non metal, and plastic type with motor 110 W to 150 W and speeds ranging from 700 rpm to 1200 rpm. Based on size of space to be conditioned, DEC are designed in various sizes ,cooling capacities that mainly depends on outside DBT, RH conditions, desired indoor condition of air, altitude, air velocities, sensible and latent heat load, orientation of condition space and number of person inside room. The design parameter to achieve thermal comfort in space to be conditioned includes total pad area, thickness of pad, material of pad, order of pad material arrangement, pressure drop across pad, speed of fan, location of cooler and ventilation condition. DEC systems are built of any sizes from a small standard room of 5m×3m to big auditorium 40m×50m with huge occupancy around 500.

Typically, the lowest temperature achieved by DEC is WBT corresponding to outdoor DBT. However, with current techniques, temperature below WBT and closed to DPT can be achieved. Performance of DEC is expressed in terms of effectiveness that varies from 0.6 to 0.9.

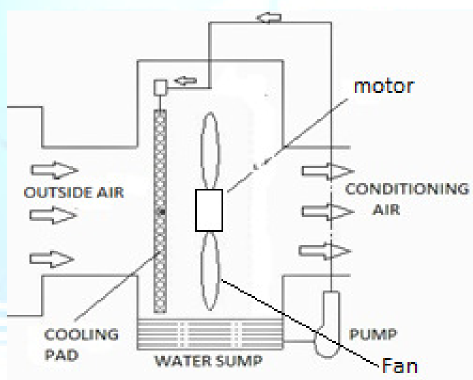

Fig.1 Evaporative cooling

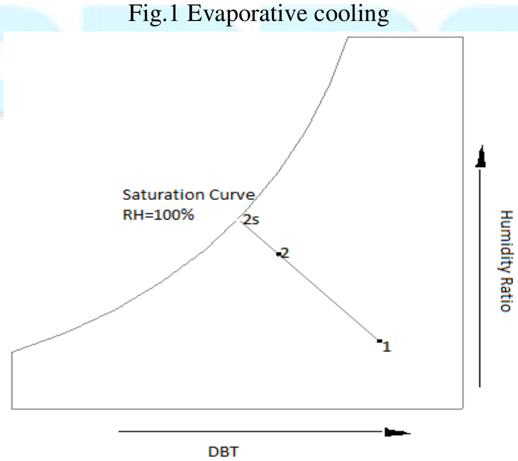

Fig. 2 Psychrometric representation of Evaporative Cooling

Fig. 3 Outdoor and Inside Conditions without Evaporative Cooling

Even though, many studies are reported over entire globe, the first significant paper is reported by Watt in 1963, who introduced scope and potential of DEC & IDEC. [3]

J. R. Camargo proposed three methods of evaluation of scope and potential of EC. The first method called feasibility index gives idea whether EC is beneficial in specific locations under test ambient conditions. He concluded that EC is effective only if WBT of ambient air is less than 24^{0}C. He applied this method to Brazilian cities. [4]

Abdul Rahoman Th. Mohammad performed experimentation for hot and humid regions where scope of EC is very limited. He obtained air temperature of 27.5^{0}C to 29.4^{0}C and Saturation efficiency of 64% to 78%. Ultimately, he concluded that EC cannot replace A.C. but first sensible heat drop can be achieved. [5]

J. K. Jain and D. A. Hidoliya investigated performance of two new pad material viz. coconut fiber and Palash fibers. They found that effectiveness of palash fibers was 13.2% more than aspen pad materials and 26% more than Khus, while effectiveness of coconut fiber is 8% more than Khus pad and almost equal to aspen. [6]

Ebrahim Hajidvallow used EC on condenser side of window air conditioner for efficient heat rejection purpose. He showed that COP of system is increase by 55% while power consumption is reduced by 16% as compared to traditional forced air cooled conditioner.[7]

Eqbal M. A. carried out study of three different pad materials viz sliced wood pads, straw pad and Celdek pads and investigated their effect on greenhouse storage fruits, flowers and vegetables. He found that sliced wood pads are better than rest of two. [8]

3. Experimental Set up:

The test facility build at SKN College of engineering Pune, to check performance of DEC is a room of 4m×3m×3m length, width and height. The total volume of test facility 36 m^3. The sensible and latent heat load at peak conditions 3600 W and 750 W contributing total of 4.35 KW peak cooling load. The DEC was designed to satisfy this cooling load.

The typical cooler arrangement includes cooling pads, fan, pump, grill assembly. Cooling pad materials are available in much variety like jute, Celdek paper, coconut, khus and aspen. The Celdek paper pad material was used for cooler as it gave least pressure drop. Parameters like area and thickness of cooler are calculated to serve the purpose. Dimensions of pad materials are 1m height and 0.75 m width. Such three pad surfaces contribute to area of 2.25 m^2. Increased thickness could have given cooler temperature at the cost of increased pressure drop. Immersed pump of 40 W with pumping capacity of 1100 LPH at a head of 1.8 m is used. Water is spread on top of three pads which then percolate while flowing downward on pad surface. The thickness of pad used is 50 mm. In order to create a strong induced draught of air, fan motor assembly with maximum speed of 1300 rpm with power 110 W is used. The whole cooler assembly is put in a tin sump with 1m×0.78m×0.15m with capacity 120 liter. The rate of evaporation certainly depends on condition of DBT, WBT of outside air.

The Celdek pad provides a wide area for heat and mass exchange between air and water. The discharge through cooler is 750 m^3 per hour. Cooler has outlet of 0.3m diameter.

The various parameters like DBT, WBT and RH is measured by sling psychrometer located simultaneously inside room and another outside room. The rotational speed of fan is measured by tachometer with accuracy ± 3 rpm. The air velocity is measured by anemometer with accuracy of ± 0.1m/s. Flow of water is measured with actual 5 liter capacity vessel and time required is measured. Solar radiation data is made available from outside sources of weather department. Fig. 3& 4 shows actual installation of cooler and test facility.

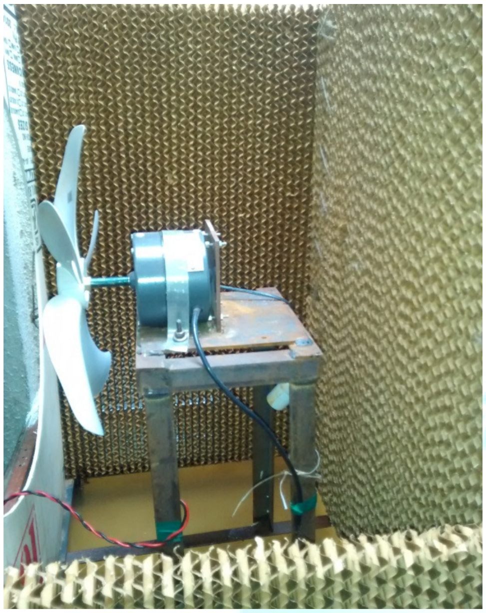

Fig. 3 Inside view of cooler

Fig. 4 Test Facility at SKNCOE

3.1. *Performance Parameters*

The performance evaluation of DEC is measured in terms of feasibility index, saturation efficiency or effectiveness and cooling capacity.

1. Feasibility Index is fast & accurate method of evaluating scope & potential of DEC for certain location under certain given climatic conditions. It is defined as

$$FI = WBT - \Delta T$$

Where,

WBT = Wet bulb temperature

ΔT = Wet bulb depression (DBT-WBT)

Smaller FI indicates more scope of EC. It is recommended that F.I. within 10 gives comfort cooling, between 10 – 15 provides relief cooling while FI above 15, does not recommend use of DEC for that location.

2.2. *Saturation Efficiency & Effectiveness*

The minimum temperature of air achieved by DEC is equal to wet bulb temperature i.e. outside air can be cooled to its corresponding WBT in simple form of DEC. It is defined as

$$\epsilon = \frac{Tout - Troom}{Tout - Twb}$$

Where,

T_{out} = DBT of outside air

T_{room} = DBT of conditioned space

T_{wb} = WBT of outside air

Effectiveness of DEC is generally in the range of 0.6 to 0.85. It depends upon pad material, pad thickness, pad density, outdoor air DBT & RH etc.

2.3. *Cooling Capacity*

As outdoor conditions vary from morning to late afternoon. Cooling Capacity of cooler varies with temperature gradient & is given by

$$Q = mCp\,(T_{out} - T_{room})$$

4. Result and Discussion:

The performance of DEC designed cooler is evaluated in this section. Pune city has geographical location as Longitude of 18.52^0N and Latitude of 73.856^0E. Pune summer is moderate with temperature ranging from 22^0 C to 40^0 C during morning to evening and outside (RH) humidity varies from 20% to 50%.

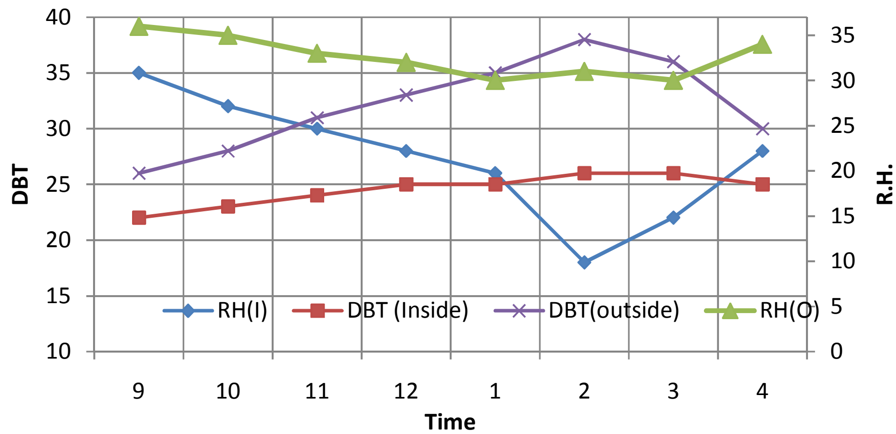

Fig. 5 Variation of DBT and RH of outdoor and indoor air

Fig 5 indicates variation of DBT and RH of outside air and inside room conditions when cooler is not in operation. It is an indication of cooling load with respect to time and it is function of building material, thickness, solar flux incident on room, inside sensible & latent heat load. As seen, use of EC is necessary in this case as RH is well below comfort limit of 40% to 60%.

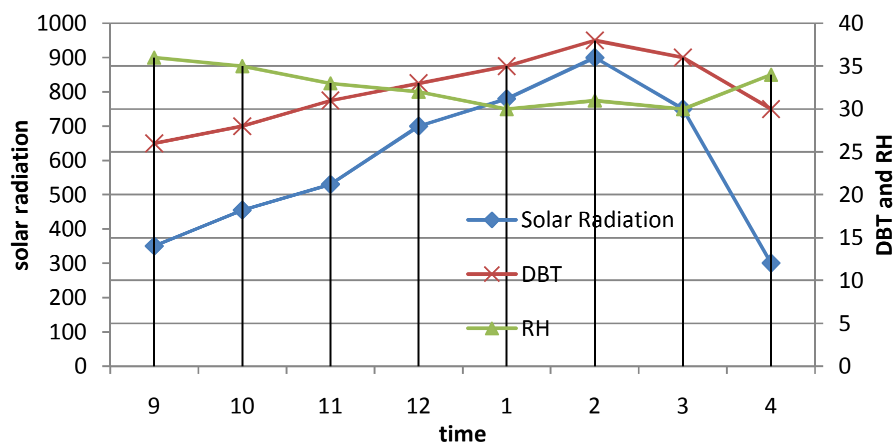

Fig.6 Variation of solar radiation, DBT,RH

Fig.6 represents at solar radiation DBT of air increases while RH of air falls. The combined results is air get hot and dry increasing sensible and latent heat load and providing better favorable conditions for DEC.

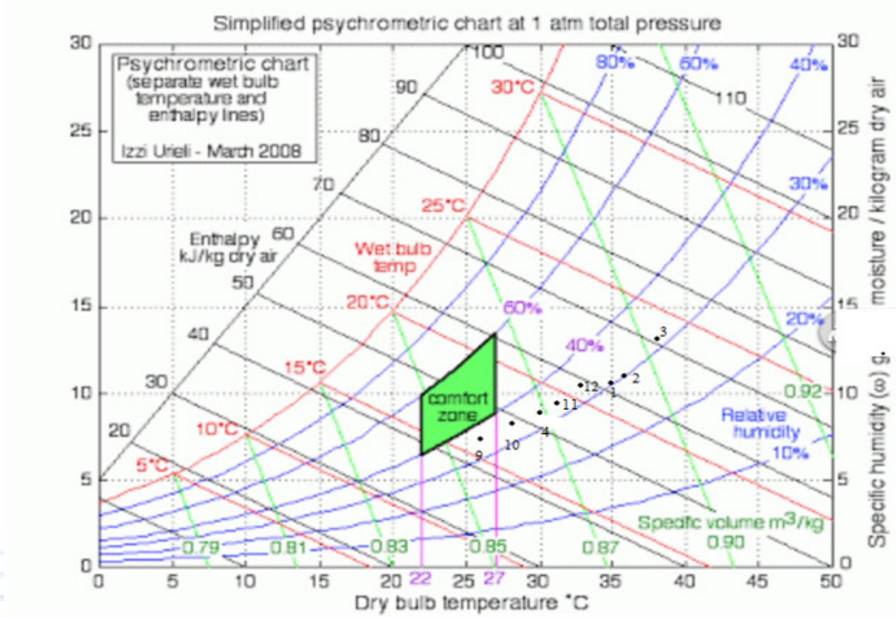

Fig.7 Room indoor conditions without EC w.r.t time

Fig.7 represents the condition of outside air away from comfort zone w.r.t time. It gives us idea of load of evaporate cooler. As seen condition of air at 9 am,10 am,11 am,12 pm and 4 pm, DEC can be used while condition at 1 pm,2 pm and 3 pm, DEC cannot be used & cooling is done with IDEC.

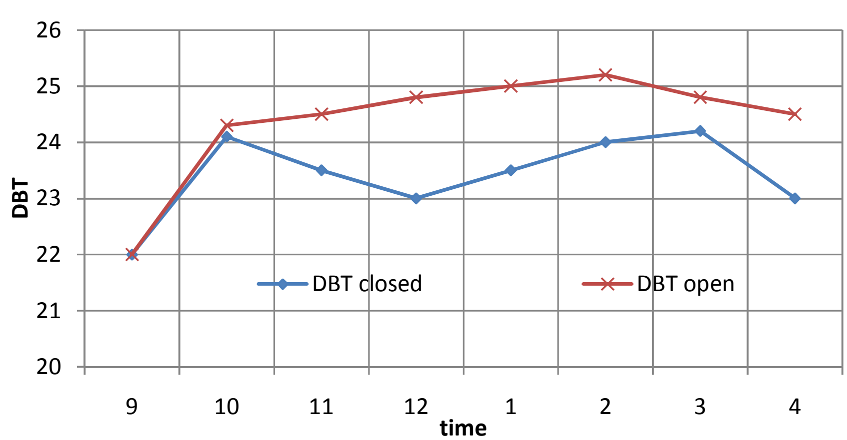

Fig.8 Variation in DBT with or without ventilation

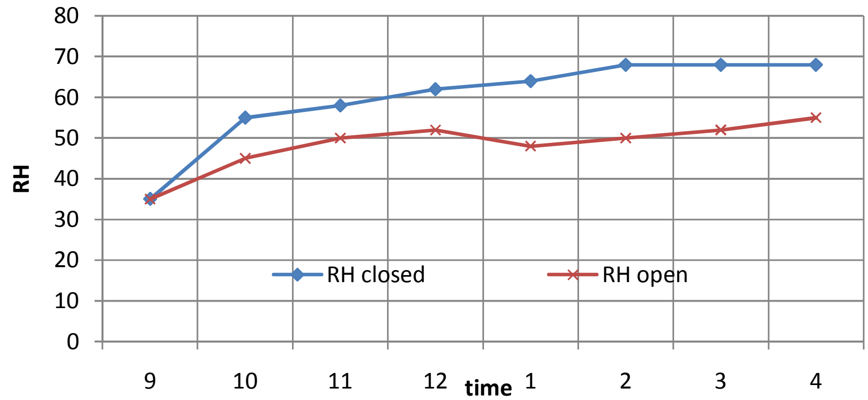

Fig.9 Variation in DBT with or without ventilation

Generally, EC uses 100% ventilation and fresh supply air. When condition space is completely close i.e. doors and windows are closed, it is found that DBT of room falls as compare to open door position. This condition is favorable but at the same time, RH inside room goes on increasing and exceeds more than 60% which is an undesirable effect. Fig. 8 & fig. 9 shows variation of DBT and RH has function of open and closed door position.

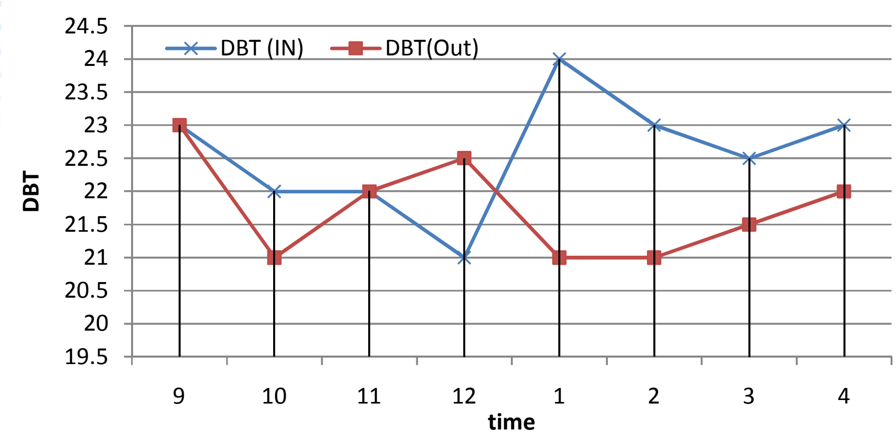

Fig.10 Effect of cooler position on DBT

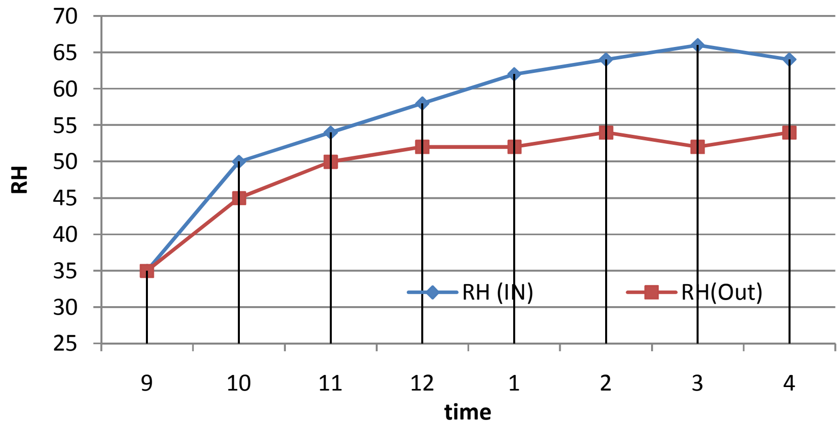

Fig. 11 Effect of cooler position on RH

Fig.10 & fig 11 represents effect of location of cooler i.e. inside or outside the room .It is found that placing cooler outside room (window) provides lower temperature in room than placing the cooler inside . Also, RH of room is maintained within comfort limits. As cooler uses variable speed motor fan .Performance of cooler is tested for various speeds & it is found better at lower speed. This may be due to more retention time of air on surface of pad and evaporation of water. At higher speeds it is observed that some water droplet are carried by exhaust fan in conditioned space which is undesirable.

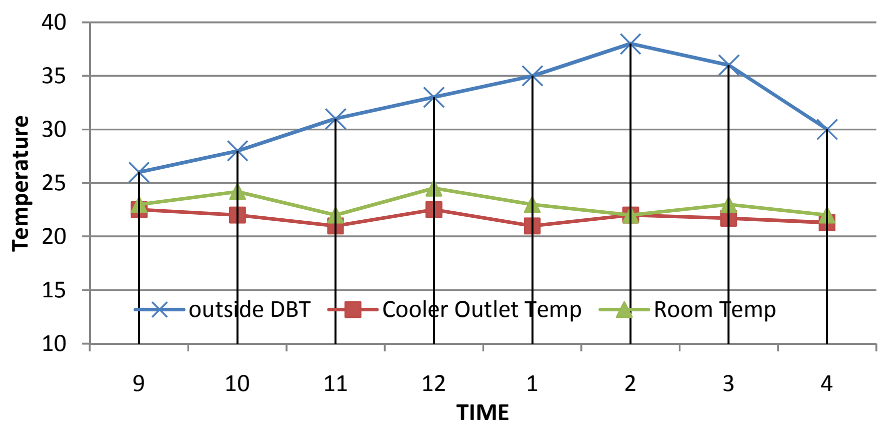

Fig. 12. Variation of outside DBT, Room Temperature and cooler outlet temperature.

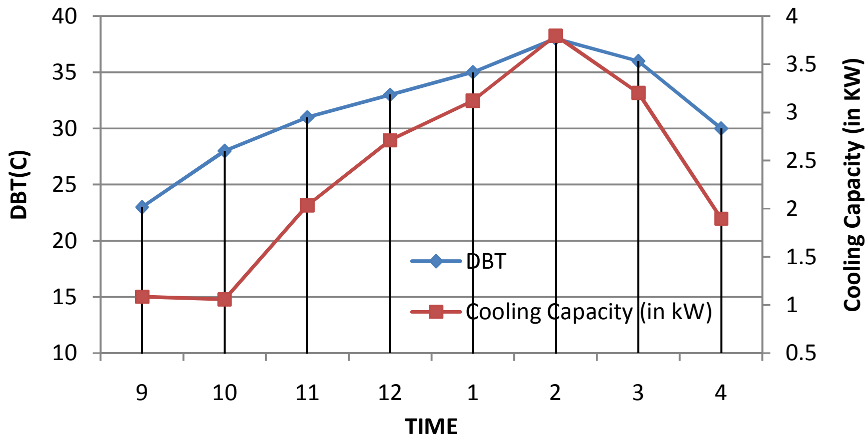

Fig. 13 Variation of cooling capacity of DEC and DBT

As seen in fig. 12, room temperature is maintained within comfortable limits of temperature between 20^0C to 24^0C. Cooling Capacity of DEC is found varying and is function of DBT of outside air. Cooling capacity is found to be 1.088 KW at 9 a.m. and maximum 3.7989 KW at 2 pm. As indicated in figure no.7 DEC can not be used during certain time. Cooler water sump temperature provide solution to this problem . As it is cooled below the WBT of air, it can be used as IEC fluid for sensible cooling of outdoor air.

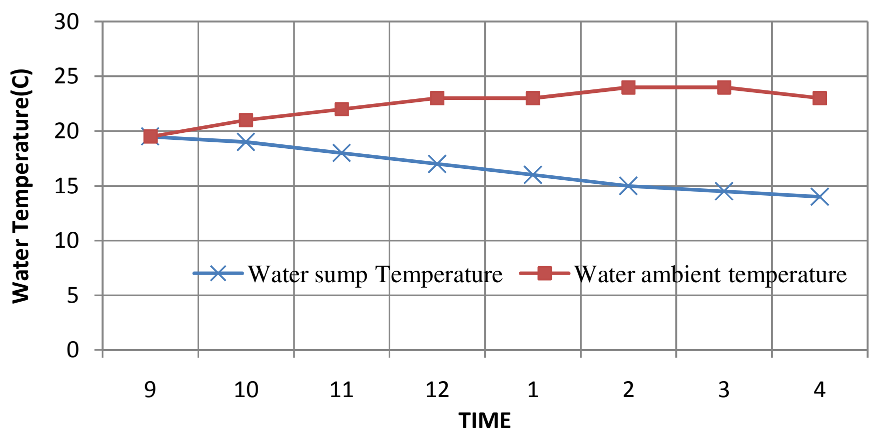

Fig.14 Variation of ambient water and sump water temp.

Fig. 14 indicates variation of sump water temperature after flowing through DEC with reference to water ambient temperature. As seen sump water temperature goes on decreasing from morning to evening. The reduced water temperature is used for operating IEC when outside RH is high.

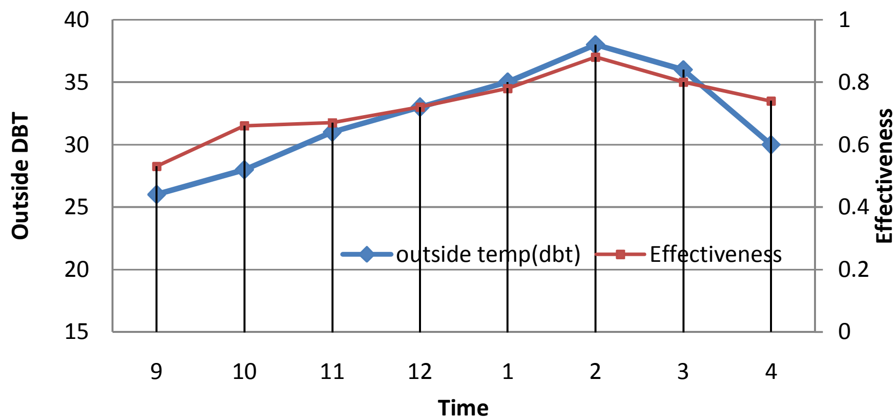

Fig.15 Variation of effectiveness of DEC

Fig. 15 shows variation in effectiveness of DEC which is increased from 0.53 to 0.88. Higher DBT provides more scope for water evaporation due to which effectiveness increases with increase in DBT.

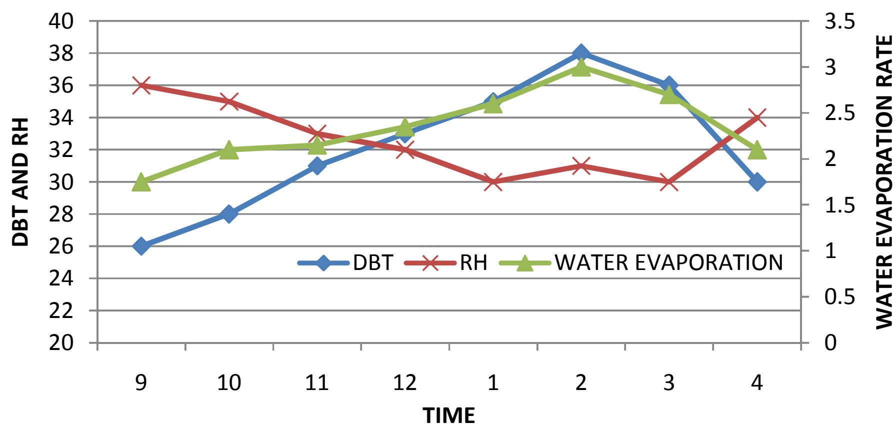

Fig.16 Variation of water evaporation with respect to DBT, RH of outside air

Typically, EC is favorable where conditions are dry & hot. In such dry regions in summer condition, there is acute shortage of water. Water evaporation rate then become an important issue. It can be reduced by proper design of pad material, selection of proper pad material, circulation of adequate water that can be evaporated. Lower water circulation will reduces effectiveness while higher water circulation increases pumping power unnecessary.

Figure 15. indicates that as DBT of outside air goes on increasing and with RH fall, water consumption increases which is quite natural. It gives us at what temperature how much water is necessary even though water is freely available in Pune but in arid regions water is bought at high price. This can increases running cost of DEC.

5. Conclusion:

Feasibility study of use of DEC for Pune summer conditions is evaluated and subsequent experimentation was carried out. It is found that Pune has moderate summer conditions with DBT & RH variations 25^0 C to 40^0 C and 20% to 40% providing favorable conditions for DEC.

As DBT of outside air increases and RH falls, effectiveness of DEC is found to be increasing. The performance of DEC is found better if the unit is placed outside the room and partial ventilation is provided. The cooling capacity of DEC goes on increasing from morning to afternoon as DBT of air increases. The sump water temperature achieved 9^0C temperature drop with corresponding WBT of air providing scope for IEC. Thus, Direct Evaporative Cooling is promising energy efficient cooling technique that possesses potential to replace air conditioners for Pune summer condition, rendering many benefits from energy, environmental, operational and economical point of view.

Nomenclature

Q_c=Cooling Capacity
T_1= Evaporating inlet DBT
T_2= Evaporating Outlet DBT
T_3= Room Temperature
Tw_1= Evaporating inlet WBT
W= Water Evaporating rate
ΔP=Pressure Drop
V m/s=Air velocity
m = mass
Cp= Specific heat

Acknowledgement

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References:

1. Ezgi Akpinar-Ferrand, Ashbindu Singh, “Modeling the increased demand of energy for air Conditioners and consequent CO_2 emissions due to health risk due to climate change in India.” Environmental Science & Policy, Volume 13, Issue 8, December 2010, pp 702-712.
2. J. R. Camargoa, C. D. Ebinumaand S. cardosoa, “Three methods to evaluate the use of evaporative cooling for human thermal comfort.” Thermal Engg, Vol.5, No.02, December 2006, pp 9-15.
3. Watt, J.R., 1963, “Evaporative air conditioning”, New York: The Industrial Press, New York 1997.
4. Abdul Rahman Th. Mohammad, “Experimental performance of a direct evaporative cooler operating in Kaula Lumpur.” Thermal & Environmental Engineering, 6, 2013, pp 15-20.
5. Jain R.K. Hindoliya D.A., “Experimental Performance of new evaporative cooling pad materials”, Renewable Energy, Volume 1, Issue 4, December 2011, pp 252-256.
6. Hojidavaloo Ebrahim, “Application of evaporative cooling on the condenser of window air conditioner”, applied thermal Engineering, Volume 27, Issue 11-12, August 2007, pp 1937-1943.
7. Egbal Mohammed Ahmed, Osama Abaas, Mohammed Ahmed, Mohd Rodzi Ismail, “Performance evaluation of three different types of local evaporative cooling pads in greenhouses in Sudan”, Energy and Buildings, Volume18, Issue 1, January 2011, pp 1235-1243.