Efficient Technique of Air-Conditioning

S. D. Suryawanshi, Tarup M. Chordia, Nikita Nenwani, Harish Bawaskar, Suraj Yambal

Abstract - Two stage evaporative cooling (TSEC) is an alternative way to provide the sustainable environment which is nearer to the comfort. System consists of multistage cooling i.e. Direct and Indirect Evaporative cooling. For producing comfort environment in educational institutes (Class-rooms, offices etc.) evaporative cooling proves its energy efficient ability. Direct evaporative cooling (DEC) have disadvantage of higher relative humidity in conditioned space. Combination of in-direct evaporative cooling (IEC) i.e. air to water heat exchanger and direct evaporative cooling gives a promising option for the same. In regard of geographic location of Pune, the variation in DBT and RH over a day is considerable. Indirect Evaporative cooling uses the sump water which is close to the wet bulb temperature of the atmospheric air. The elevated relative humidity after direct evaporative cooling is reduced by mixing the outlet air from indirect evaporative cooling. Based on psychometric calculations the average output air temperature and relative humidity of the system ranges from 21 to 26°C and 50 to 65% respectively. In energy terms pumps and blower are the major energy consuming devices. Two stage evaporative cooling is 4.5 times efficient than conventional HVAC.

Keywords: **- Direct evaporative cooling, In-direct evaporative cooling, adiabatic process, sensible cooling, Two stage evaporative cooling, HVAC.**

I. INTRODUCTION

India is facing grave crisis due to acute shortage of electrical energy and ever growing demand. With 80,000MW of installed capacity country needs an additional 80,000MW during the next five years. Even a 5% saving in electricity will prevent the need to install power plants of a few thousand MW. The present energy scenario created awareness among the building designers and architects to maximize use of the non conventional energy sources, such as solar energy, wind energy, geo-thermal energy etc. leading to saving in energy consumed in building. At current rates, the world uses fossil fuels 100,000 times faster than they can form. The demand for them will far outstrip their availability in a matter of centuries-or less.

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Energy conservation is the need of the hour. The known reserves of oil and natural gas may last hardly for 25 to 30 years respectively at the current reserves to production ratio. India has huge proven coal reserves (84 billion tonnes), which may last for about 200 years but the increasing ash content in Indian coal as well as associated greenhouse gas emissions are the major concern.

Cooling performance of two-stage indirect/direct evaporative cooling system is experimentally investigated in
the various simulated climatic conditions [1]. Results shows 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 range of 108–111%. Aspects of achieving comfort conditions and power saving have been investigated with related excess water consumption. More than 60% power saving could be obtained by this system in comparison with conventional HVAC 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 conventional HVAC as energy efficient and environmentally clean alternate.

The option of using evaporative cooling, for a specific application and under certain climatic condition, will be a viable one if the following two conditions can be simultaneously satisfied [2]:

1. Limiting the supply-air-flow rate to an acceptable value; taking into consideration space constraints, noise level, energy efficiency and economical factors.
2. Maintaining the indoor relative humidity within a tolerable range commensurate with the application nature or requirements.

The realization of these two objectives may, sometimes, necessitate switching from a simple or basic, configuration to a more sophisticated two-stage system.

Indirect evaporative cooling is a sustainable method for cooling of air. The main constraint that limits the wide use of evaporative coolers is the lowest temperature of the process, which is the wet bulb temperature of ambient air. Indirect evaporative cooling method is presented to produce air at a sub-wet bulb temperature without using a conventional HVAC [3]. The main idea consists of

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manipulating the air flow inside the cooler by branching the working air from the product air, which is indirectly pre-cooled, before it is finally cooled and delivered. A model for the heat and mass transfer process is developed. Four types of coolers are studied: three two-stage coolers (a counter flow, a parallel flow and a combined parallel-regenerative flow) and a single-stage counter flow regenerative cooler. It is concluded that the proposed method for indirect evaporative cooling is capable of cooling air to temperatures lower than the ambient air wet bulb temperature. The lowest temperature for such a process is the dew point temperature of the ambient air. The wet bulb cooling effectiveness (Ewb) for the examples studied is 1.26, 1.09 and 1.31 for the two-stage counter flow, parallel flow and combined parallel-regenerative cooler, respectively, and it is 1.16 for the single-stage counter flow regenerative cooler. Such a method extends the potential of useful utilisation of evaporative coolers for cooling of buildings as well as other industrial applications.

Using of experimental data and an appropriate analytical method, the performance and energy reduction capability of combined system has been evaluated through the cooling season [4]. The results indicate IEC can reduce cooling load up to 75% during cooling seasons. Also, 55% reduction in electrical energy consumption of PUAC (packaged unit air conditioner) can be obtained.

Two-stage evaporative cooler (TSEC) consists of the heat exchanger and two evaporative cooling chambers. The performance of cooler has been evaluated in terms of temperature drop, efficiency of the evaporative cooling and effectiveness of TSEC over single evaporation [5]. The temperature drop through TSEC ranged from 8 to 16°C. With the several observations for diurnal runs, it was observed that TSEC could drop the temperature up to wet bulb depression of ambient air and provided the 90% relative humidity. Efficiency of single evaporation was 85–90%. Effectiveness of the two-stage evaporative cooling was found to be 1.1–1.2 over single evaporation. The two-stage evaporative cooler provided the room conditions as 17–25°C temperature and 50–75% relative humidity, which can enable to enhance the shelf-life of wide range of fruit and vegetables of moderate respiration rates.

Rick Phillips [6] presents how to maximize saving in HVAC system using direct evaporative cooling (DEC) combined with chilled water coils.

II. METHODOLOGY

The scope for energy conservation in commercial sectors lies within the following areas: HVAC, Computers, Lighting, Fan and other Instruments (7). From Pie Chart it can be concluded that the major energy consuming device is Air conditioning (56%). The energy consumption of Air conditioning is depend upon heating or cooling load. There are many ways and technologies developed to reduce the load on Air conditioning. Some of them are solar refrigeration, air curtain, orientation of building, thermal insulation, double pane glass etc.

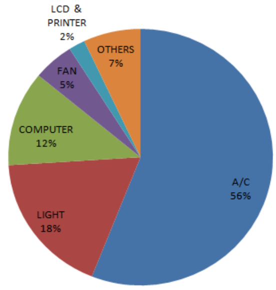

Fig 1 Distribution of Energy Usage in Commercial Sector

But still these are very less effective. The major reason of more energy consumption of Air conditioning is the comfort level. As Air conditioning tries to achieve the comfort level the energy consumption increases. It is true that there are some application where comfort level is required but to reduce energy consumption, sustainable enviornment should be provided where comfort level is not essential. The parameters like temperature(26-27°C), relative humidity(50-65%) is slightly more than the comfort level in sustainable environment .

III. INNOVATIVE CONCEPT OF SUSTAINABLE ENVIRONMENT

For producing comfort environment in various areas like educational institutes, residential buildings, offices etc. evaporative cooling proves its energy efficient ability. Direct evaporative cooling have disadvantage of higher relative humidity in conditioned space. In-direct evaporative cooling i.e. air to water heat exchanger gives a promising option for the same. A case study of a cabin in Mechanical Engineering department of College of Engineering Pune, is considered for modification and analytical study of two stage evaporative cooling.

The basic idea of project is to cool the air by using multistage evaporative cooling. As shown in fig.2, Blower is used to blow the air through the duct over the coil carrying water from tank. While passing over the coil, temperature of air will drop. This is in-direct Evaporative cooling. After sensible cooling, the part cool air goes to direct evaporative cooling and the remaining part goes through the bypass. In second stage of direct evaporative cooling is achieved. But at this point the relative humidity of the air will reach to 90 - 100%, which is not favorable for conditioned space. To restrict exit relative humidity up to 60-65% the air from bypass is mixed with the outlet air of direct evaporative cooling with ratio of 1:1. Due to mixing of air the elevated relative humidity is brought down within the comfort zone

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as shown in fig.3. But the temperature of mixed air is more than the outlet air temperature of direct evaporative cooling. This system uses 100% fresh air.

The cold air is supplied through ducts in room. Air-conditioning system with no compressors, chemicals and only blowers are required to move the air, consume less energy as compared to conventional air conditioning system. The amount of heat exchanged between the air and the water in heat exchanger of indirect evaporative cooling is a function of the parameters like surface area of the pipe walls, length of pipe, inlet air temperature, and velocity of air in duct, material of the pipe, and surface conditions of the pipe walls.

IV. ANALYSIS OF DATA FROM INDIAN METROLOGICAL DEPARTMENT PUNE

The data available from Indian Metrological Department Pune of 2007 presented in table 1 and 2[(8)]. The data indicates that in the months of March, April and May, the average dry bulb temperature ranges (DBT) from 32 to 38^{0}C between 12pm to 5pm. These are the 5 working hours of day, required conditioning in the cabin under consideration.

The fig. 4 and 5 shows that, as DBT increases, the relative humidity decreases. These conditions are most favourable for direct as well as indirect evaporative cooling of air. From table1 and 2, we can conclude that during the day time i.e. in between 12pm to 5pm value of DBT is very high compared to other time slots of day. At the same time value of relative humidity is low compared to other time slots of the day. This is the favourable condition of giving low value of wet bulb temperature (WBT). The water can be cooled up to the respective WBT of these hours.

V. SAMPLE CALCULATION OF AIR COOLING

Day: 27 April (peak temp out of three summer month)
DBT_1: 41^{o}C
RH_1: 16%
WBT_1: 21.27^{o}C
Wet bulb depression = 41-21.27 = 19.73^{0}C
Assuming 40% efficiency of indirect evaporative cooling, the temperature drop is 19.73*0.4 = 7.9^{o}C.
Outlet temperature (DBT_2) after IEC is = 41-7.9= 33.1^{o}C
RH_2 = 24.7%
WBT_2= 18.85^{o}C = WBT_3

After direct evaporative cooling, RH is 90% & DBT_3 is 19.98^{o}C. Air from direct evaporative cooling is mixed with the bypass air.

By using the Psychometric chart, supply air temperature (DBT4) to conditioned space is **26.51^{o}C** due to duct heat gain it may be rise up to 27.5^{o}C.

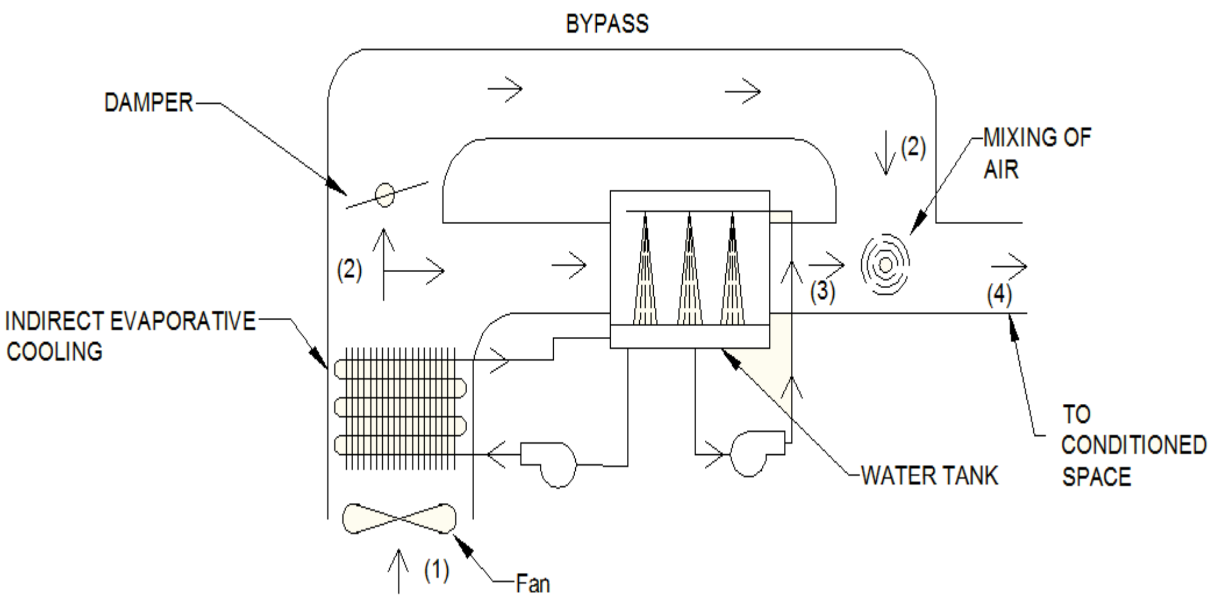

Fig.2-Flow Diagram of System

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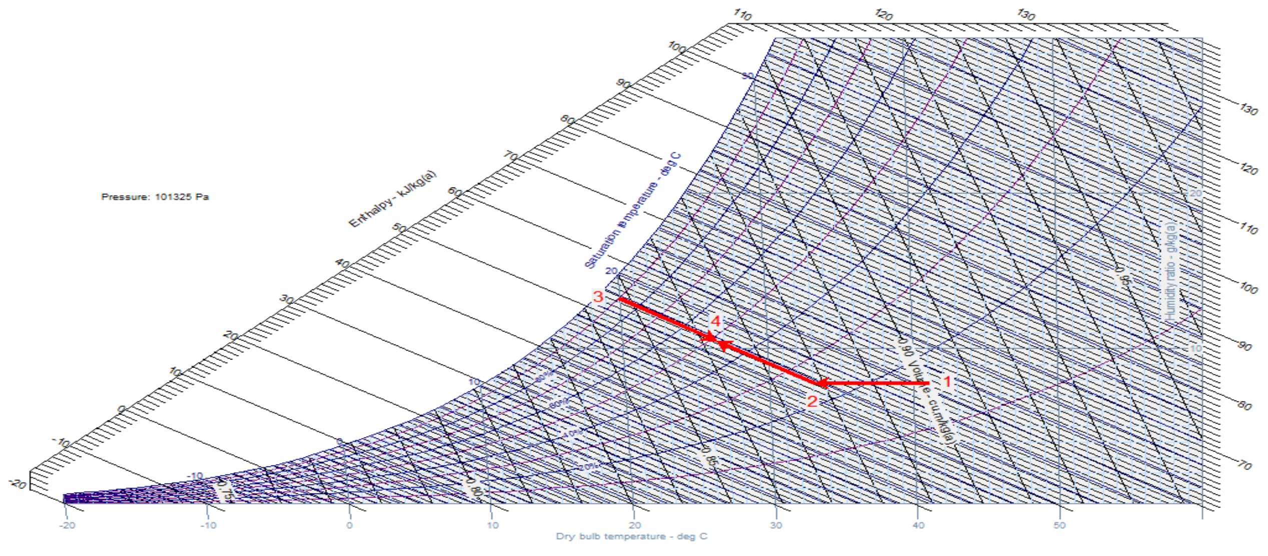

Fig.3-Psychrometric Representation of Entire Process.

TABLE 1

	12PM			1PM			2PM		
	DBT	RH	WBT	DBT	RH	WBT	DBT	RH	WBT
MAR	32.3967	20.6333	17.36556	33.458	18.1	17.365	34.2064	17.2666	17.41
APRIL	35.6666	22.1612	19.88278	36.7833	20.3225	20.07444	37.3	19.4193	20.13111
MAY	33.7193	35.7419	21.96278	34.8	31.7096	21.79444	35.2612	30.9677	21.94167

TABLE 2

	3PM			4PM			5PM		
	DBT	RH	WBT	DBT	RH	WBT	DBT	RH	WBT
MAR	34.6709	17.5333	17.9516	34.4354	18.3	18.0227	33.9645	20.8333	18.7216
APRIL	37.6066	19.1935	20.2544	37.2966	20.3548	20.4105	36.3933	21.3225	20.6983
MAY	35.0419	31.7741	21.9861	34.6645	32.9677	22.0044	33.6548	37.2258	23.0222

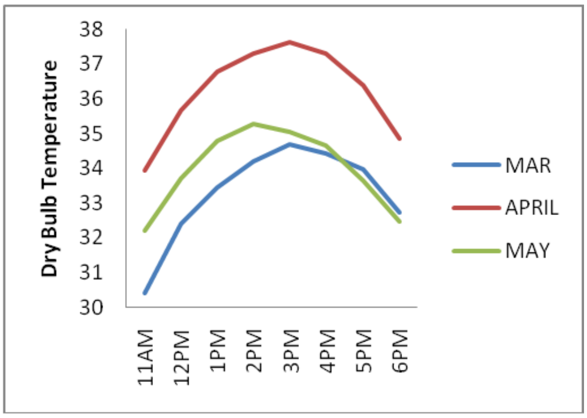

Fig.4- Dry Bulb Temperature vs. Time

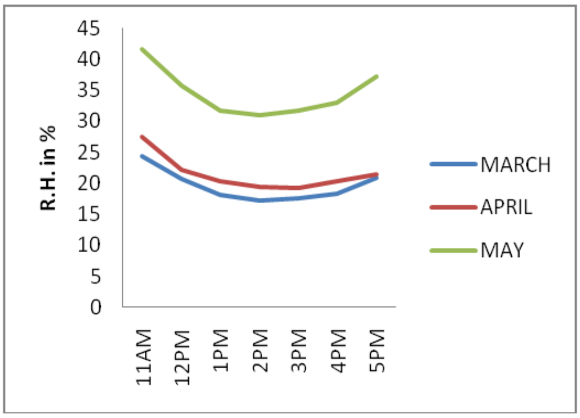

Fig.5- Relative Humidity vs. Time

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VI. EVAPORATION LOSSES (MAKE UP WATER REQUIREMENT)

- Water tank capacity = 120 litres
- Evaporation process time = 5hrs
- Circulation rate = 700 litres/hr = 0.7m^3/hr
- Evaporation loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x (T_1-T_2)
- T_1-T_2 = Temperature difference between inlet and outlet water
- Evaporation loss = 0.00085 x 1.8 x 0.7 x (35-22)
  = 0.013923 m^3/hr
  = 13.92 litres/hr
- Total evaporation loss for 5 hours = 70 litres/day

VII. ANNUAL SAVING:

- Present electricity Rate is 5.72 Rs/Unit
- No. of working hours per day= 5 hrs

A. Air Conditioner:-

- Electricity consumption of Air conditioner is 1.35 kW/TR
- Cooling load of room is 1TR.
- Total electricity consumption of A/C = 6.75kWhr/day
- Potential saving = 6.75*5.72 = 38.61Rs/day
- No of working days per month = 22
- No of Months of Working per year = 4
- Total Working days = 88 /year
- Annual Consumption of air conditioning = (88*38.61) = Rs3397.68/year

B. Two stage evaporative cooling:-

- Energy requirement of pumps is (30W*2)*5hrs =0.3kWhr
- Blower consumption is 240W = 240*5hrs = 1.2kWhr
- Total annual expenditure = (5.72*88*1.5) = Rs 755.04/year
- Actual Saving = Rs(3397.68-755.04) = Rs 2642.64

VIII. RESULTS: -

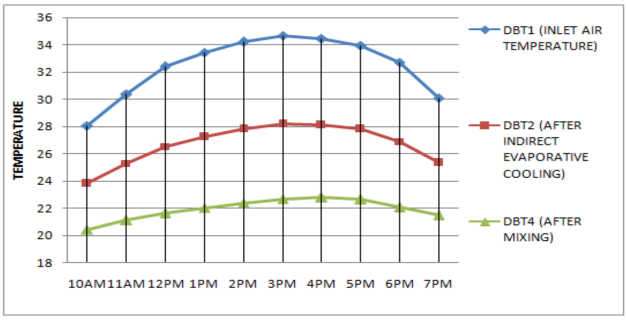

Fig.6- Diurnal variation of psychrometric monthly average properties of air for March

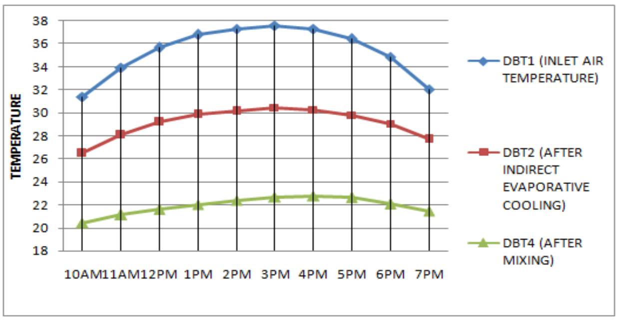

Fig.7- Diurnal variation of psychrometric monthly average properties of air for April

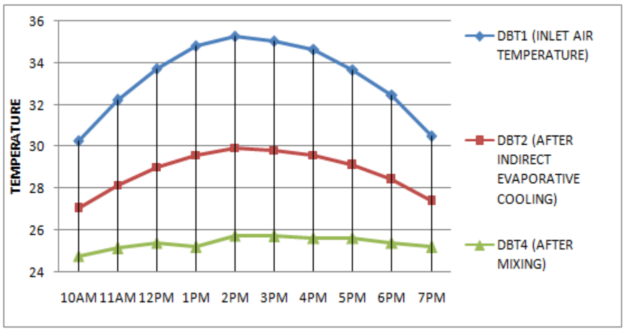

Fig.8- Diurnal variation of psychrometric monthly average properties of air for May.

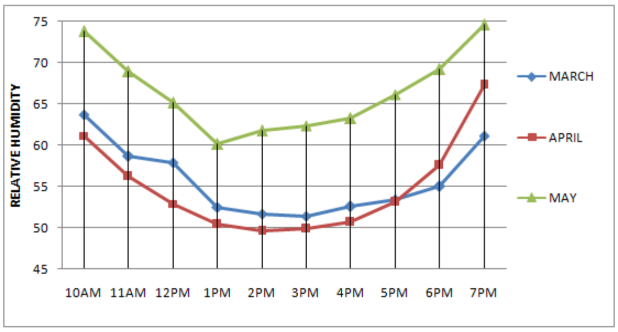

Fig.9- Diurnal variation of Relative Humidity.

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IX. COMPARISON

A. *ADVANTAGES:*

1. Output of the system is close to comfort zone.
2. Use of low power consuming devices (i.e. compressor is eliminated)
3. More economical technique than conventional HVAC
4. 100% ventilation
5. No use of chemical refrigerant
6. CO_2 emission is reduced.
7. Less adverse effect of refrigerant leakage.
8. Comparable cost with HVAC system.

B. *LIMITATIONS:*

1. Initial investment is more than single stage evaporative cooling.
2. It cannot achieve comfort condition
3. Less efficient in hot and humid Climate
4. It requires makeup water daily.
5. As the cooling load increases the required quantity of water will increase so as the size of the tank.
6. Due to 100% ventilation, the coldness present in return air is wasted in atmosphere.

X. CONCLUSION:

The fig.6, 7, 8 and 9 shows diurnal variation of air at various points of system. According to these results it is conclude that the average output air temperature and relative humidity of the system ranges from 21 to 26^{o}C and 50 to 65% respectively. The data from IMD department shows that the peak temperature is observed in March, April, May months. These results are close to comfort zone condition. It can be concluded that wherever the comfort condition are not essential this system can provide sustainable environment satisfactorily with energy efficiency.

The major drawback of the system is, it is less efficient in hot and humid climate. The system efficiency can be increased by the use of desiccants, which will reduce the relative humidity as well as the wet bulb temperature at inlet.

This system is very economical and low power consuming. The study shows that for 1TR cooling load it saves 5.25units per day as compared to conventional air conditioning. The system is 4.5 times efficient than conventional HVAC.

NOMENCLATURE:

DBT	Dry bulb temperature	^{o}C
WBT	Wet bulb temperature	^{o}C
TR	Tons of Refrigeration	-

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