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Design, Development & Testing of Nocturnally Cooled VCC Assisted Evaporative Cooler

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ABSTRACT

Technologies which do not utilize humidity for producing cooling effect have been introduced earlier. But high cost and lower EER have been seen to be its virtue. The technology which deals with the utilization of humidity is more cost effective. The basic factor in the same is the wet bulb temperature achieved. The conventional evaporative coolers act a heat exchanger and the least temperatures achieved cannot reach lower than the wet bulb temperature. These disadvantages have been covered in the evaporative cooler with assistance of vapour compression cycle along with the concept of nocturnal cooling of water.

Various cities in Maharashtra have varied climatic conditions. Cities such as Pune have hot semi-arid climatic conditions. Mumbai has hot and humid climate mostly throughout the year. Interiors such as Jalgaon face hot and dry climate while Solapur has dry (arid and semiarid) climate. Therefore it is needed to condition the air for human comfort. Air conditioners have high initial and running cost and many refrigerants also aid in global warming and ozone depletion. Also they recirculate the same air making it stale and impure. Hence, this can be effectively replaced by a hybrid evaporative cooling system in turn supplying fresh air and also saving a lot of energy. By using this system on solar energy, it is possible to minimize the running cost, but will increase its initial investment cost. This system includes use of nocturnally cooled water for VCC assisted Direct Evaporative cooling. It is based on a concept that when water is naturally exposed to the cold air at night it loses its heat by radiation to atmosphere, and maximum cooling is achieved. This apparatus makes different combinations of psychrometric processes possible, thus giving comfort condition for any weather condition throughout the year.

Keywords: ***Evaporative cooler, Vapour compression cycle, Nocturnal cooling.***

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1. INTRODUCTION

India is a growing economy, developing country and a potential future superpower. Urbanization has immensely increased in the past few years. Air conditioning is not just a luxury anymore, but is the need of the hour. It finds its applications in domestic homes, industrial areas, commercial buildings, malls and theatres, etc. Yet there are a few drawbacks of air conditioning that urge us to find better solutions. CFC emissions are high due to some refrigerants, it has high running cost, they work on electricity, in turn depending on non-renewable sources. Also global warming impulses us to use more of air conditioning, but AC itself causes global warming, hence it is a vicious circle.

Air conditioning is a process of maintaining required temperature and humidity in a confined space. It can be used for cooling and dehumidification of outdoor air. Also various processes such as heating, cooling, de-humidification, cleaning, ventilation, or air movement can be achieved. It basically works on a simple VCC (Vapour Compression Cycle), which includes 4 main operating devices viz. a compressor, condenser, expansion device and evaporator coil. The air is passed over the evaporator coil to obtain cool air.

Direct Evaporative Air Cooler is a device that cools the air through evaporation of water. The resulting air is thus of much lower temperature than ambient air and moisture is added in it as well. The cooling potential depends on the wet bulb depression or the difference between dry bulb and wet bulb temperature. So air coolers are most effective in areas of lower humidity or dry regions. So they aren’t as effective in coastal regions such as Mumbai, Chennai. They are most effective in arid climatic regions. At such places, Indirect Evaporative Coolers can be used. In it, cool liquid is passed through a coil, over which air is passed, thus decreasing its temperature. In modern times, indirect-direct evaporative coolers have emerged, which use the advantages of both the cooling techniques to obtain better indoor conditions.

Factors affecting human comfort are temperature, humidity, air movement and air purity. For human comfort, the temperature should range between 22°C to 27°C, depending on the weather conditions, Relative Humidity (RH) should lie between 40% and 60%. The air movement must be from 0.1 m/s to 0.2m/s considering sedentary activity and 1 met of metabolism rate. These factors when in certain limits provide human comfort. But the outside conditions are not always in these limits. By using various combinations of cooling, heating, humidification, dehumidification processes we can achieve the required conditions.

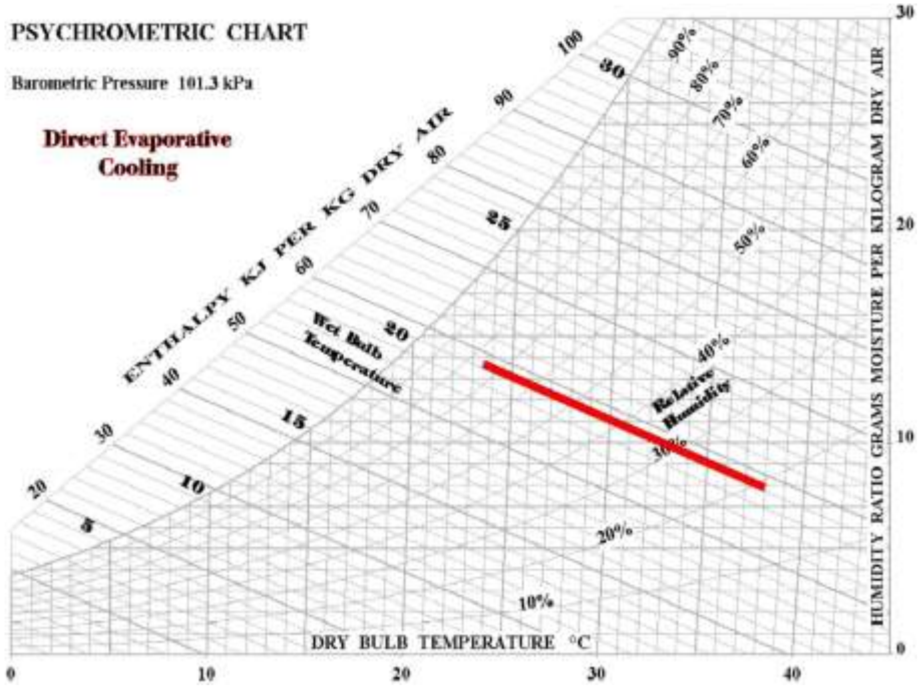

Fig-1: Psychrometric chart showing direct evaporative cooling

Atmospheric air consists of 78.08% Nitrogen, 20.95% Oxygen, and 0.04% Carbon Dioxide by volume. When air conditioner is operated in a room full of people for longer periods, the oxygen content reduces, while the CO_2 content increases which is not desirable for the respiratory system. CO_2 should be within 600ppm, and above 1000ppm is considered hazardous for health. Hence it is important to maintain the correct levels of constituents within the air.

Radiative cooling is a technique used for cooling the roofs of buildings which is based on the heat transfer from the roofs to the low temperature skies. Similarly, when water is kept exposed to atmosphere during nights, its temperature is reduced drastically by transfer of heat to low temperature air. For, Pune weather conditions, the lowest dry bulb temperature recorded for a particular year during January is 10.4°C and making WBT 9.72°C. Even during the summer, for the hottest day in May, the DBT at night reaches 22.4°C and WBT 20.06°C. This indicates that there is huge potential in this cold water to be used for cooling during the peak hours of high temperature. A traditional earthen pot can be effectively used to store this water. These pots are porous in nature and hence, the water due to its capillary action reaches the outer surface of the pot and transfers heat to the surrounding air. This reduces the water temperature to minimum and can be used for evaporative cooling for the following day.

Non-renewable sources of energy such as fossil fuels, when burnt produce harmful products. They are utilized for generation of electricity causing it to deplete at very fast rates. Alternative sources of energy should hence be preferred. Solar energy is a clean and renewable source of energy which can be harnessed for the electrical use. In spite of its high initial cost, it is used because of its quick payback period. Also it has no adverse effects on the environment. So, solar farms are being setup in different parts of the country. Solar farm in Kamuthi in Tamil Nadu, is the largest in India which has a capacity of 648 MW. Solar photovoltaic panels can be used for running of this system.

2. DESCRIPTION OF EXPERIMENTAL SETUP

Conventional Evaporative Cooler is capable of producing temperatures about 25°C to 27°C in peak summer rendering relief cooling while AC provides comfort cooling. The experiment setup consists of an arrangement by which the evaporator of typical refrigeration coil is immersed into the sump of an evaporative cooler. The temperature drop of water obtained is 10°C in peak summer conditions. The water is cooled to a minimum of 4 to 5°C and temperature of air at the outlet of cooler is around 15°C. The load on this VCC system can be reduced by using nocturnally cooled water. This water from the earthen pots is insulated and stored for peak hours.

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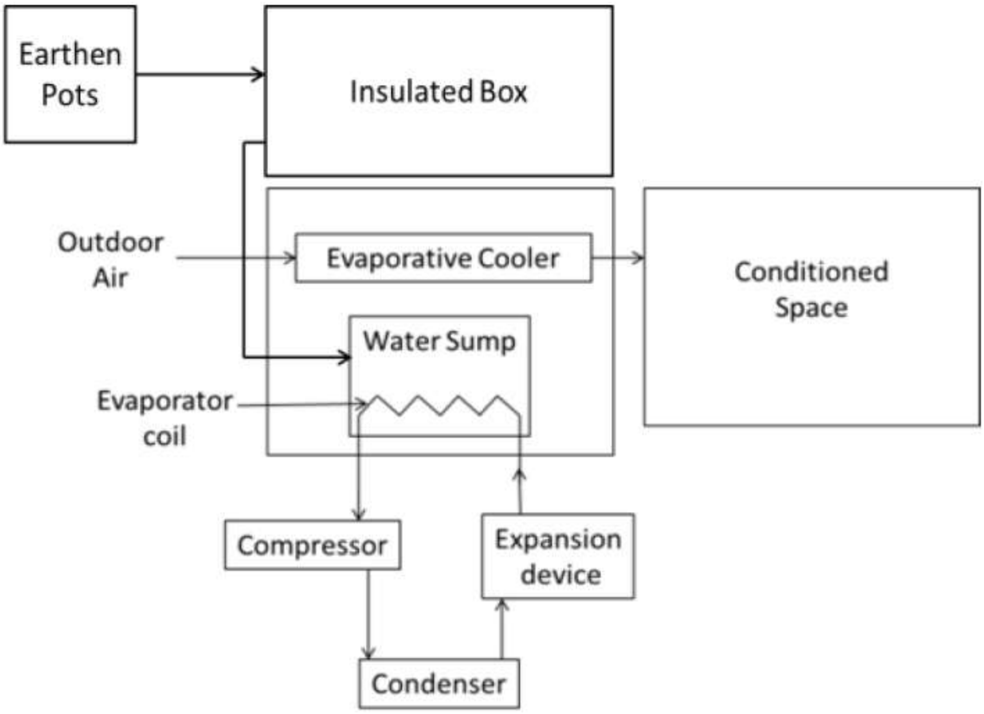

Fig-2: Experimental setup.

The experimental setup primarily consists of a DEC. The water supplied to the DEC is nocturnally cooled first. Hence this cool water is supplied to a sump. The DEC uses water from the sump. The DEC consists of a motor of 105W, and a fan connected to it. The cooler has specifically engineered cellulose paper evaporative cooling pads from three sides. Water from the sump is pumped up and is allowed to flow through the pads. The forced air due to fan gets this moisture and the RH increases. A system working on vapour compression cycle is installed to the DEC such that the evaporator of the system dips in the water sump making contact only with the water in sump. Nocturnally cooled water which is stored in the earthen pot during the night time is passed and stored in the insulated tank made of thermocole. It is circulated to the sump during peak requirements of lower temperature in the cooled room. This nocturnally cooled water thus reduces the load on the evaporator of the VCC up to some extent and limits the condenser pressure. During the summer season when it is impossible for evaporative cooler to reduce the temperature further, this arrangement could be very useful. By using the various arrangements, it can be possible to achieve different combinations of processes like cooling and humidification, sensible cooling etc. Finally the conditioned, fresh air is passed to the room to be cooled. Unlike air conditioner, fresh air is supplied to the room with levels of oxygen, carbon dioxide within limits. This arrangement can also be run on solar energy.

Equipment used for the setup consists of an electric motor of 105 W, compressor of $1/8^{th}$ HP and a water pump of 18 W. Considering time of operation of setup as 8 hours a day which gives the power consumption of approximately 2 kW-h per day requiring a photovoltaic type solar panel of capacity 300 W. PV solar panel absorbs solar energy and produces electrical DC output. This output produced is then passed through the solar charge controller to charge the battery to run the system. Also, it could be connected to an inverter to directly run the connected components.

The heat load on VCC system for 50 litres of water in the sump to reach a temperature difference of 10°C is 2094 kJ. Compressor power requirement of one eighth HP amounts to 350J/s of heat extraction from water. 1.7 hours of VCC system operation ensures the temperature difference in sump water expected earlier.

3. RESULTS

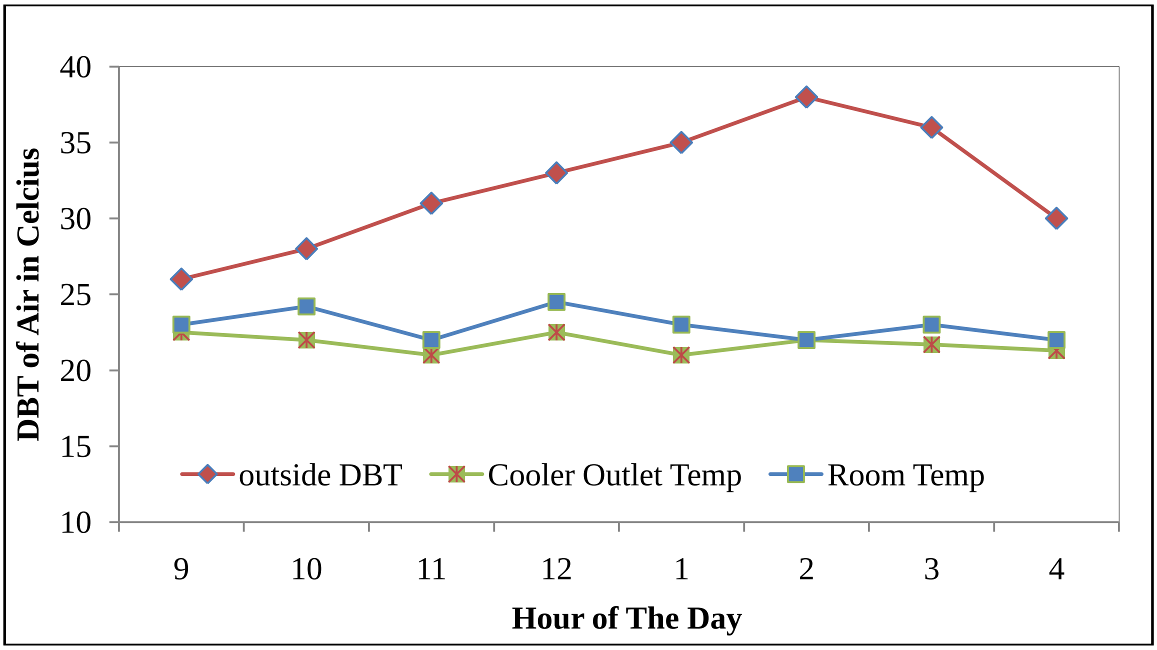

Fig-3: Difference in DBT of outdoor air, room air and cooler outlet air

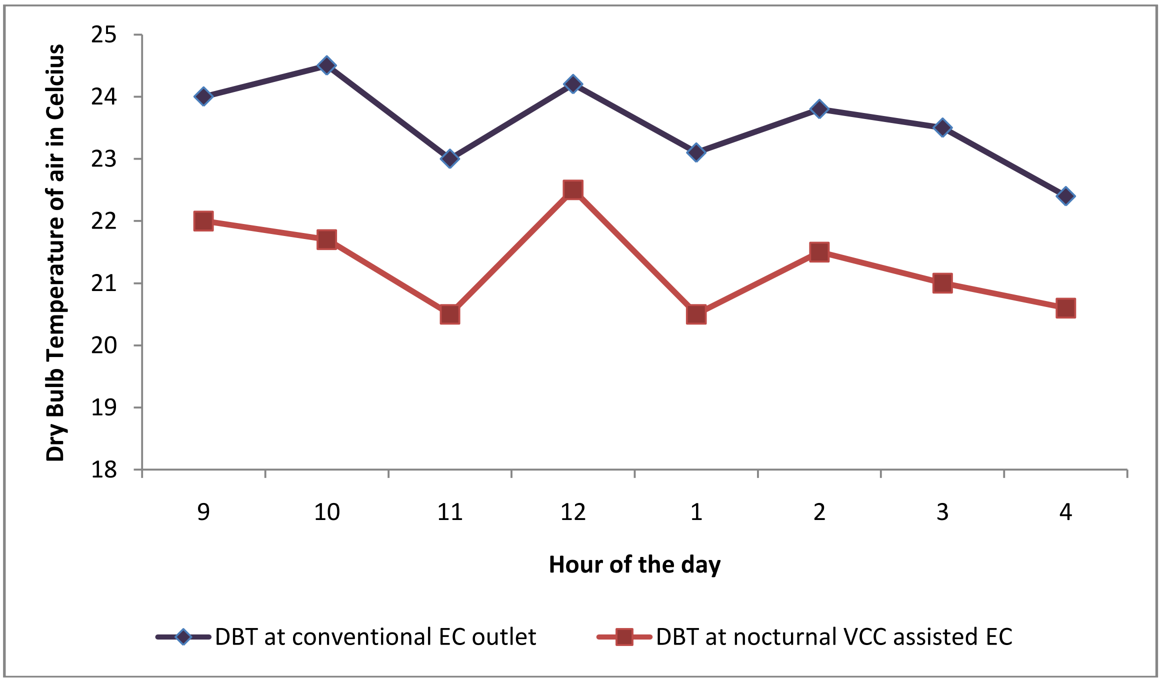

Fig-4: Comparison of DBT at conventional and new EC outlet.

The results that have been observed and a noticeable difference can be seen in the temperatures after using air with VCC assisted cooler. Even at peak hours of the day we can obtain the temperatures with comfort limits. Fig-3 describes the comparison between ambient air, the inside temperature and temperature after using the cooler. On the other hand, fig-4 describes the comparison between air we get at the end of the regular air cooler and the one with using a VCC assisted air cooler.

4. CONCLUSION

Nocturnal or radiative cooling is the best technique possible to cool the water with no cost. Nocturnal cooling system used with DEC has a great potential to replace the Air Conditioner with reduced amount of power consumption and effective measure of controlling relative humidity.

In arid environment evaporative cooling can be used effectively, as it does not require additional humidity increase or air movement. Cooled, Fresh and clean air is provided to the room with adequate air velocity. No harmful releases in the environment by using this totally green system. Nocturnal cooling can be effective in achieving lower temperatures in summer as well.

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