THERMAL PERFORMANCE ANALYSIS OF PUMP LESS EARTHERN PIPE EVAPORATIVE AIR COOLER

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Abstract

Evaporative air cooler is of prime importance in summer season and hot conditions. Cooler is widely used everywhere from high class to middle class families. The heart of a modified evaporative cooling system is the ceramic material tube where the water goes inside the tube and due to the property of porosity of the tube water comes out the outer surface of the tube and comes in contact with air passing besides the tube and air get cooled. The ceramic material tube in which one end are close and other end are open. The circulation of air is due to the creation of negative pressure produced by fan.

***Keywords*— Evaporative cooler, ceramic, porosity.**

I. INTRODUCTION

An evaporative cooler (also swamp cooler, desert cooler and wet air cooler) is a device that cools air through the simple evaporation of water. [1] Evaporative cooling differs from vapour compression refrigeration system (VCRS) and vapour absorptive refrigeration system (VARS), which use vapour-compression or absorption refrigeration cycles. In dry, arid climates, the installation and operating cost of an evaporative cooler can be much lower than that of VCRS, often by 80% or so. However, evaporative cooling and vapour-compression air conditioning are sometimes used in combination to yield optimal cooling results. Some evaporative coolers may also serve as humidifiers in the heating season. In locations with moderate humidity there are many cost-effective uses for evaporative cooling, in addition to their widespread use in dry climates. For example, industrial plants, commercial kitchens, laundries, dry cleaners, greenhouses, spot cooling (loading docks, warehouses, factories, construction sites, athletic events, workshops, garages, and kennels) and confinement farming (poultry ranches, hog, and dairy) often employ evaporative cooling. In highly humid climates, evaporative cooling may have little thermal comfort benefit beyond the increased ventilation and air movement it provides. An evaporative cooler produces effective cooling by combining natural process i.e. water evaporation with a simple, reliable air-moving system. Fresh outside air is pulled through moist pads where it is cooled by evaporation and circulated through a house or building by a large blower. As this happens, the temperature of the outside air can be lowered as much as 30 degrees. Probably because evaporative coolers add moisture to the air and blow it around, they are sometimes known as "swamp coolers." Evaporative coolers can work efficiently, Provided the outside air they are drawing is dry and desert-like. However As the humidity increases, however, the ability for them to cool the air effectively decreases. Simply put, swamp coolers were not designed to work in swamp-like conditions. Air conditioners can require ozone-damaging refrigerants, and they recirculate the same air over and over in highly humid climates evaporative cooling may little thermal comfort benefit beyond the increased ventilation and air movement it provides.

CERAMIC

A ceramic is an inorganic, non-metallic solid prepared by the action of heat and subsequent cooling. [2] Ceramic materials may have a crystalline or partly crystalline structure, or may be amorphous (e.g., a glass). Because most common ceramics are crystalline, the definition of ceramic is often restricted to inorganic crystalline materials, as opposed to the non-crystalline glasses. The earliest ceramics were pottery objects made from clay, either by itself or mixed with other materials, hardened in fire. Later ceramics were glazed and fired to create a colored, smooth surface. Ceramics now include domestic, industrial and building products and art objects. In the 20th century, new ceramic materials were developed for use in advanced ceramic engineering, for example, in semiconductors. A ceramic material is often understood as restricted to inorganic crystalline oxide material. It is solid and inert. Ceramic materials are brittle, hard, strong in compression, weak in shearing and tension. They withstand chemical erosion that occurs in other materials subjected to acidic or caustic environment. Ceramics generally can withstand very high temperatures such as temperatures that range from 1,000 °C to 1,600 °C (1,800 °F to 3,000 °F).

Classification of technical ceramics.
Technical ceramics can also be classified into three distinct material categories:

- Oxides: - alumina, beryllia, ceria, zirconia
- Non-oxides: - carbide, boride, nitride, silicide
- Composites: - Particulate reinforced combinations of oxides and non-oxides.

Each one of these classes can develop unique material properties because ceramics tend to be crystalline.

Examples of white ware ceramics.

- Earthenware: - which is often made from clay, quartz and feldspar. [3]
- Stoneware: - Porcelain, which are often made from kaolin Bone china.

So we introduce a modified evaporative cooling system which cools air and produce low humidity in air without using water pump & also replacing pad's with ceramic pipe's which will save electricity & water consumption. Our ceramic pipes are made of normal mud used for making water pots which is present in abundant. It is cheaply available everywhere & it is easy to process.

Evaporative air cooling.

Evaporative cooling is a physical phenomenon in which evaporation of a liquid, typically into surrounding air, cools an object or a liquid in contact with it. Latent heat describes the amount of heat that is needed to evaporate the liquid; this heat comes from the liquid itself and the surrounding gas and surfaces. When considering water evaporating into air, the wet-bulb temperature, as compared to the air's dry-bulb temperature, is a measure of the potential for evaporative cooling. The greater the difference between the two temperatures, the greater the evaporative cooling effect. When the temperatures are the same, no net evaporation of water in air occurs, thus there is no cooling effect. A simple example of natural evaporative cooling is perspiration or sweat which the body secretes in order to cool itself. The amount of heat transfer depends on the evaporation rate, which in turn depends on the humidity of the air and its temperature, which is why one's sweat accumulates more on hot, humid days: the perspiration cannot evaporate. A recent application of evaporative cooling is the "self-refrigerating" beverage can. A separate compartment inside the can contains a desiccant and cooling liquid. Just before consumption, the desiccant comes into contact with the cooling liquid, inducing evaporation. Evaporative cooling is a very common form of cooling buildings for thermal comfort since it is relatively cheap and requires less energy than many other forms of cooling. However, evaporative cooling requires an abundant water source as an evaporate, and is only efficient when the relative humidity is low, restricting its effective use to dry climates.

Humidification Process.

The process in which the moisture or water vapour or humidity is added to the air without changing its dry bulb (DB) temperature is called as humidification process. This process is represented by a straight vertical line on the psychrometric chart starting from the initial value of relative humidity, extending upwards and ending at the final value of the relative humidity. In actual practice the pure humidification process is not possible, since the humidification is always accompanied by cooling or heating of the air.

Cooling and Humidification Process.

Cooling and humidification process is one of the most commonly used air conditioning application for the cooling purposes. [4] In this process the moisture is added to the air by passing it over the stream or spray of water which is at temperature lower than the dry bulb temperature of the air. When the ordinary air passes over the stream of water, the particles of water present within the stream tend to get evaporated by giving up the heat to the stream. The evaporated water is absorbed by the air so its moisture content, thus the humidity increases. At the same time, since the temperature of the absorbed moisture is less than the DB bulb temperature of the air, there is reduction in the overall temperature of the air. Since the heat is released in the stream or spray of water, its temperature increases. One of the most popular applications of cooling and humidification is the evaporative cooler, also called as the desert cooler. The evaporative cooler is the sort of big box inside which is a small water tank, small water pump and the fan. The water from the tank is circulated by the pump and is also sprayed inside the box. The fan blows strong currents of air over the water sprays, thus cooling the air and humidifying it simultaneously. The evaporative cooler is highly effective cooling devise having very low initial and running cost compared to the unitary air conditioners. For cooling purposes, the cooling and humidification process can be used only in dry and hot climates like desert areas, countries like India, China, and Africa etc. This cooling process cannot be used in hot and high humidity climates. The cooling and humidification process is also used in various industries like textile, where certain level of temperature and moisture content has to be maintained. In such cases large quantity of water is sprayed, and large blowers are used to blow the air over the spray of water. During the cooling and humidification process the dry bulb of the air reduces, its wet bulb and the dew point temperature increases, while its moisture content and thus the relative humidity also increases. Also the sensible heat of the air reduces, while the latent heat of the air increases resulting in the overall increase in the enthalpy of the air. Cooling and humidification process is represented by an angular line on the psychrometric chart starting from the given value of the dry bulb temperature and the relative humidity and extending upwards toward left.

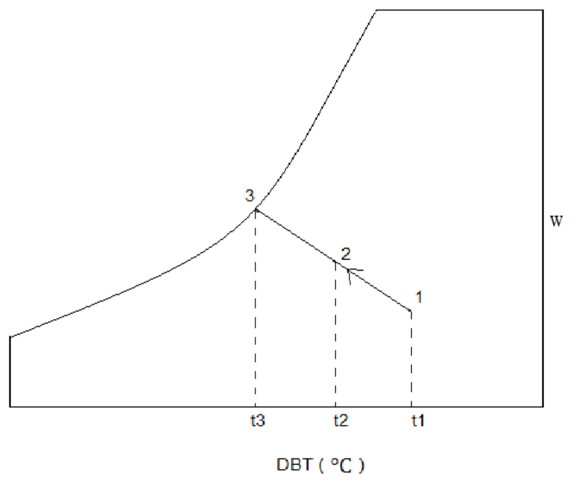


Fig.1 Cooling and humidification process

Where,
t_1 = inlet air dry blub temperature.
t_2 = air dry bulb temperature after cooling.
t_3 = ideal cooling temperature.
w = Relative humidity.

II. PARAMETERS FOR ANALYSIS

Psychrometrics

Psychrometrics or psychrometry are terms used to describe the field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapour mixtures. The term derives from the Greek *psuchron* meaning "cold" and metron meaning "means of measurement". Common applications. Although the principles of psychrometry apply to any physical system consisting of gas-vapour mixtures, the most common system of interest is the mixture of water vapour and air, because of its application in heating, ventilating, and air-conditioning and meteorology. In human terms, our comfort is in large part a consequence of, not just the temperature of the surrounding air, but (because we cool ourselves via perspiration) the extent to which that air is saturated with water vapour.

Dry-bulb temperature (*DBT*) is that temperature of an air sample, as determined by an ordinary thermometer, the thermometer's bulb being dry. [5] It is typically the abscissa (horizontal axis) of the graph. The SI units for temperature are Kelvin or degrees Celsius; other units are degrees Fahrenheit and degrees Rankine.

Wet-bulb temperature (WBT) is that temperature of an air sample after it has passed through a constant-pressure, ideal, adiabatic saturation process, i.e. after the air has passed over a large surface of liquid water in an insulated channel. [6] In practice, this is the reading of a thermometer whose sensing bulb is covered with a wet sock evaporating into a rapid stream of the sample air. When the air sample is saturated with water, the WBT will read the same as the DBT. The slope of the line of constant WBT reflects the heat of vaporization of the water required to saturate the air of a given relative humidity.

Dew point temperature (*DPT*) is that temperature at which a moist air sample at the same pressure would reach water vapour "saturation". At this point further removal of heat would result in water vapour condensing into liquid water fog or (if below freezing) solid hoarfrost. The dew point temperature is measured easily and provides useful information, but is normally not considered an independent property of the air sample. It duplicates information available via other humidity properties and the saturation curve.

Relative humidity (*RH*) is the ratio of the mole fraction of water vapour to the mole fraction of saturated moist air at the same temperature and pressure [7]. RH is dimensionless, and is usually expressed as a percentage. Lines of constant RH reflect the physics of air and water: they are determined via experimental measurement. It may be noted that the notion that air "holds" moisture or moisture "dissolves" in dry air and saturates the solution at some proportion is an erroneous (albeit widespread) concept.

Humidity ratio (also known as moisture content or mixing ratio) is the proportion of mass of water vapour per unit mass of dry air at the given conditions (DBT, WBT, DPT, RH, etc.). It is typically the ordinate (vertical axis) of the graph. For a given DBT there will be a particular humidity ratio for which the air sample is at 100% relative humidity. The relationship reflects the physics of water and air and must be measured. Humidity ratio is dimensionless but is sometimes expressed as grams of water per kilogram of dry air or grains of water per pound of air (7000 grains equal 1 pound). Specific humidity is closely related to humidity ratio but always lower in value as it expresses the proportion of the mass of water vapour per unit mass of the air sample (dry air plus the water vapour).

Specific enthalpy symbolized by '*h'*, also called heat content per unit mass is the sum of the internal (heat) energy of the moist air in question including the heat of the air and water vapour within. In the approximation of ideal gases, lines of constant enthalpy are parallel to lines of constant WBT. Enthalpy is given in (SI) joules per kilogram of air or BTU per pound of dry air.

Specific volume also called inverse of density is the volume per unit mass of the air sample. The SI units are cubic meters per kilogram of dry air; other units are cubic feet per pound of dry air.

INSTRUMENTATION USED

- A small pump less ceramic pipe cooler whose specification is shown below in the table 1.
- Dry and wet bulb thermometers for measurement of dry bulb and wet bulb temperatures.
- Pshychrometric charts for calculation of relative and specific humidity.

- A velocity measurement instrument (Anemometer).

III. DETAILED SPECIFICATION OF PIPE & COOLER

Hollow pipes made of ceramic material.

We have taken outer diameter of pipes as 3.5 cm & inner diameter of the pipes as 2 cm. Length of pipes is 16 inches. In our cooler we have used 17 pipes. In which 7 are fitted at back side of cooler & 5 pipes at both sides. Our ceramic pipes are made of normal mud used for making water pots which is present in abundant, cheaply available everywhere & easy to process. It is made from GI sheet die .It is heated at 70 °C for five hours. Traditional ceramic raw materials include clay minerals such as kaolinite. The physical properties of any ceramic substance are a direct result of its crystalline structure and chemical composition. A material's strength is dependent on its microstructure. The engineering processes to which a material is subjected can alter this microstructure. Theoretically, a material could be made infinitely strong if the grains are made infinitely small.

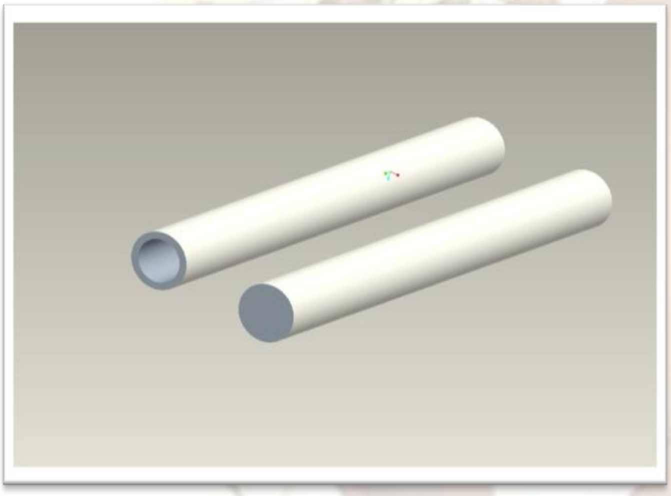


Fig.2 Ceramic pipes.

A rectangular metal box.

It is made from GI sheet of 20 gauge.Sheet metal is simply metal formed into thin and flat pieces. It is one of the fundamental forms used in metalworking, and can be cut and bent into a variety of different shapes. Countless everyday objects are constructed of the material. Thicknesses can vary significantly, although extremely thin thicknesses are considered as foil or leaf, and pieces thicker than 6 mm (0.25 in) are considered plate. Sheet metal is available as flat pieces or as a coiled strip. The coils are formed by running a continuous sheet of metal through a roll slitter. The thickness of the sheet metal is called its gauge. The gauge of sheet metal ranges from 30 gauge to about 8 gauge. The larger the gauge number, the thinner the metal. There are many different metals that can be made into sheet metal, such as aluminium, brass, copper, steel, tin, nickel and titanium. For decorative uses, important sheet metals include silver, gold, and platinum (platinum sheet metal is also utilized as a catalyst.) The sheet metal gauge (sometimes spelled gage) indicates the standard thickness of sheet metal for a specific material. For most materials, as the gauge number increases, the material thickness decreases. Sheet metal thickness gauges for steel are based on the weight of steel, allowing more efficient calculation of the cost of material used. The weight of steel is 41.82 pounds per square foot per inch of thickness (8039 kg/m^3); this is known as the Manufacturers Standard Gage for Sheet Steel. For other materials such as aluminium and brass the thicknesses will be different.

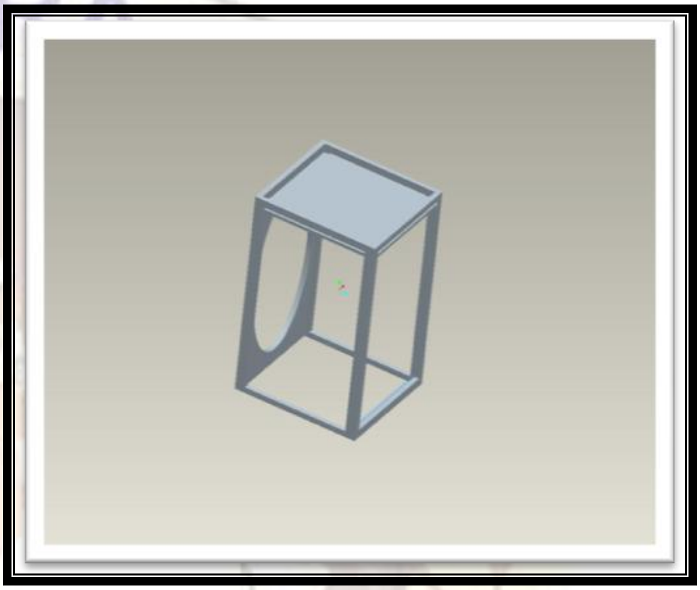


Fig.3 Rectangular box.

PARAMETERS	SPECIFICATIONS
DIMENSIONS	19.5” X 14.5”
BLOWER/FAN	90 WATTS
SUPPLY VOLTAGE	220 VOLTS A.C.
EFFECTIVE COOLING AREA	15 X 12 FEET ROOM
ELECTRIC CONSUMPTION	90 WATTS /H
WATER SUMP CAPACITY	7 litre

Table.1

Fig.4 Modified cooler

IV. ARRANGEMENT OF PIPES IN COOLER.

Fig.5 Left side view of cooler.

Fig.6 Back side view of cooler.

V. ANALYSIS & OBSERVATIONS

Observations are done in summer season at Bhopal, M.P. India. Bhopal has a humid subtropical climate with mild, dry winters, a hot summer and a humid monsoon season. Summers start in late March and go on till mid-June, the average temperature being around 30 °C (86 °F), with the peak of summer in May, when the highs regularly exceed 40 °C (104 °F). [8]

1) Outdoor DBT 35.8°C at 12:00 pm

Fan air velocity (m/sec)	DBT(°C) after cooling	WBT (°C) after cooling	RH % after cooling
1	33.5	25.2	52
2.3	32.0	24.7	57
4.7	31.1	24.0	60
7.0	29.2	23.0	61

Table 2

Inlet air temperature

t_1=35.8°C

Air temperature after cooling

t_2=29.2°C
Actual cooling temperature
t_3=24.5°C
Now efficiency of the cooler at 12:00 pm
η= (t_2-t_3/t_1-t_3)*100%
η = (29.2-24.5/35.8-24.5)*100%
η=71.2%

2) Outdoor DBT 37.1°C at 02:00 pm

Fan air velocity (m/sec)	DBT(°C) after cooling	WBT (°C) after cooling	RH % after cooling
1	33.1	26.2	60
2.3	32.2	26	62
4.7	31	25.7	63
7.0	30.1	25	64

Table 3

Inlet air temperature
t_1=37.1°C
Air temperature after cooling
t_2=30.1°C
Actual cooling temperature
t_3=25°C
Now efficiency of the cooler at 02:00 pm

η = (t_2-t_3/t_1-t_3)*100%
η = (30.1-25)/37.1-25)*100%
η = 72.8%

3) Outdoor DBT 39°C at 04:00 pm

Fan air velocity (m/sec)	DBT(°C) after cooling	WBT (°C) after cooling	RH % after cooling
1	35.1	28.3	62
2.3	34	28	65
4.7	33.3	27.7	66
7.0	32	27	68

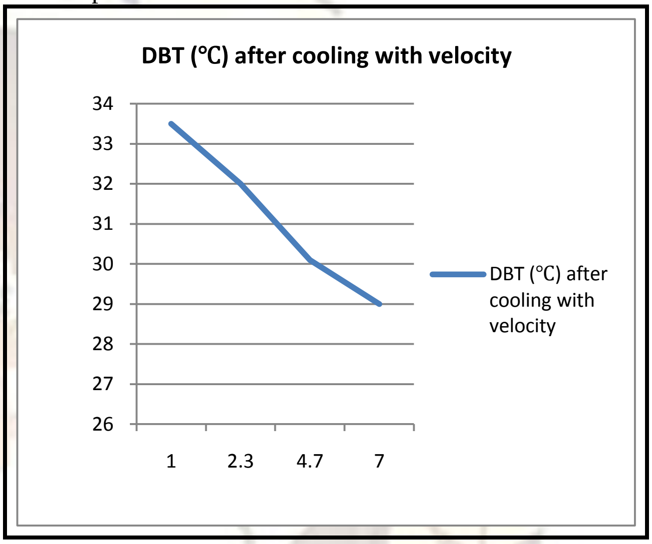
Table 4

Inlet air temperature
t_1=37.1°C
Air temperature after cooling
t_2=30.1°C
Actual cooling temperature
t_3=25°C
Now efficiency of the cooler at 04:00 pm

η= (t_2-t_3/t_1-t_3)*100%
η = (32-27/39-27)*100%
η= 71.4%

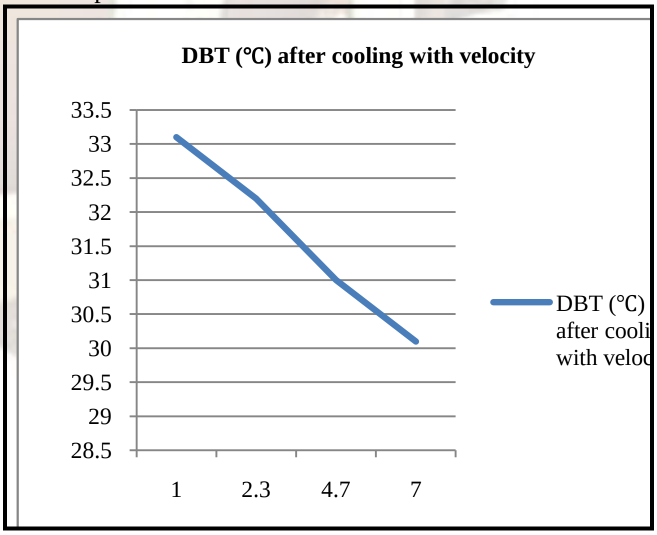
VI. RESULT & DISCUSSION

At 12:00 pm



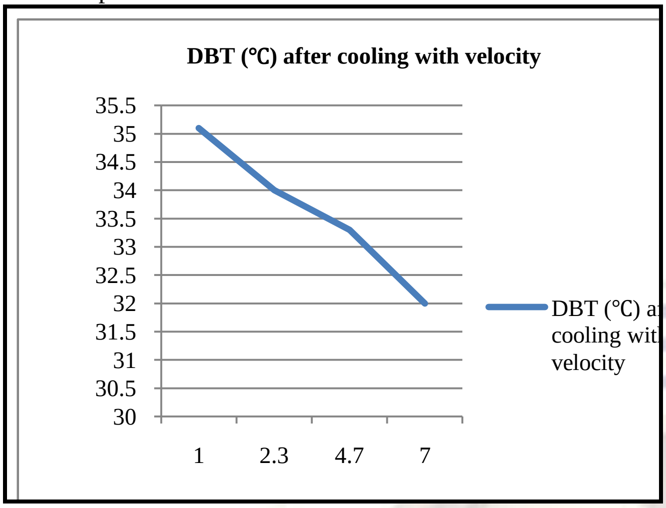
Graph 1. Between DBT (°C) after cooling and velocity (m/sec)

At 02:00 pm



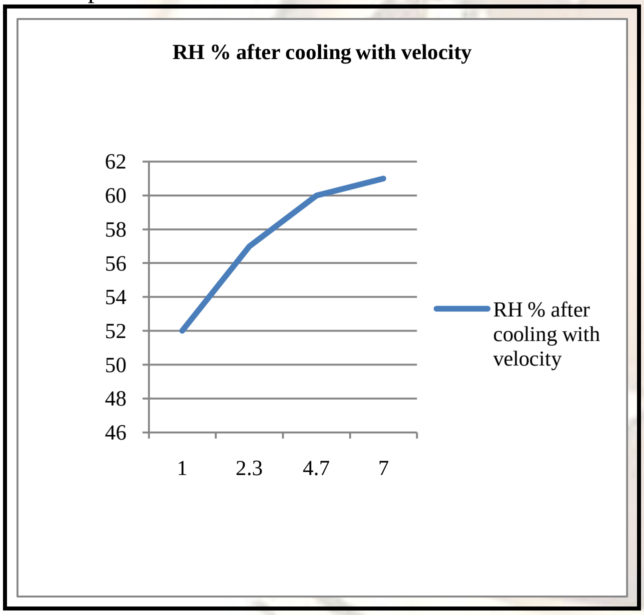
Graph 2. Between DBT (°C) after cooling and velocity (m/sec)

At 04:00 pm



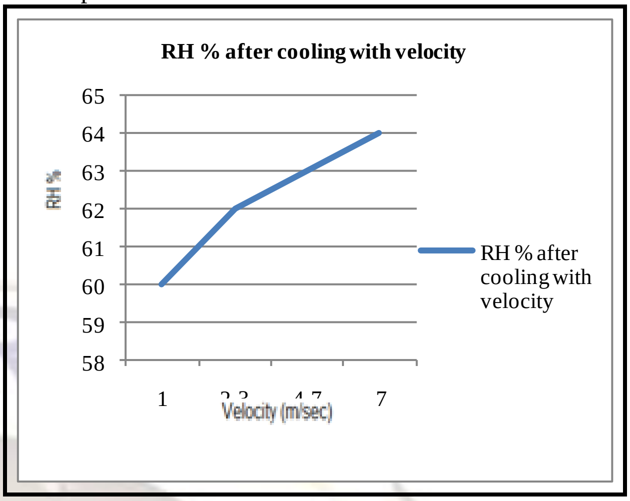
Graph 3. Between DBT (°C) after cooling and velocity (m/sec)

At 12:00 pm



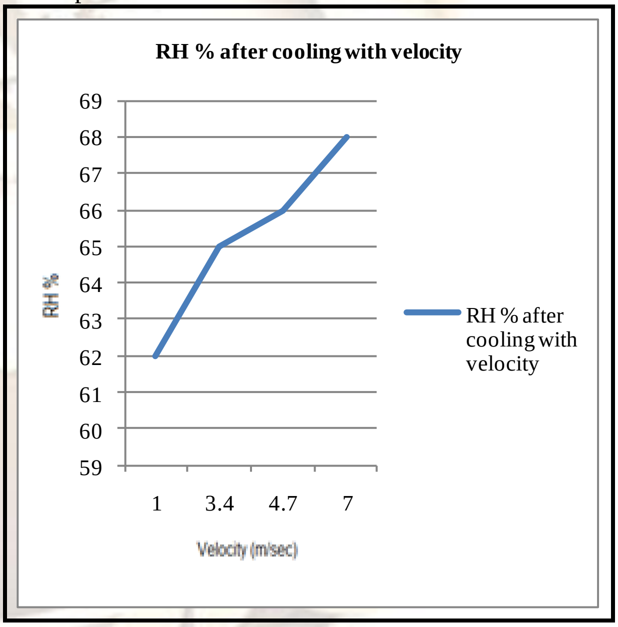
Graph 4. Between RH % after cooling and velocity (m/sec)

At 02:00 pm



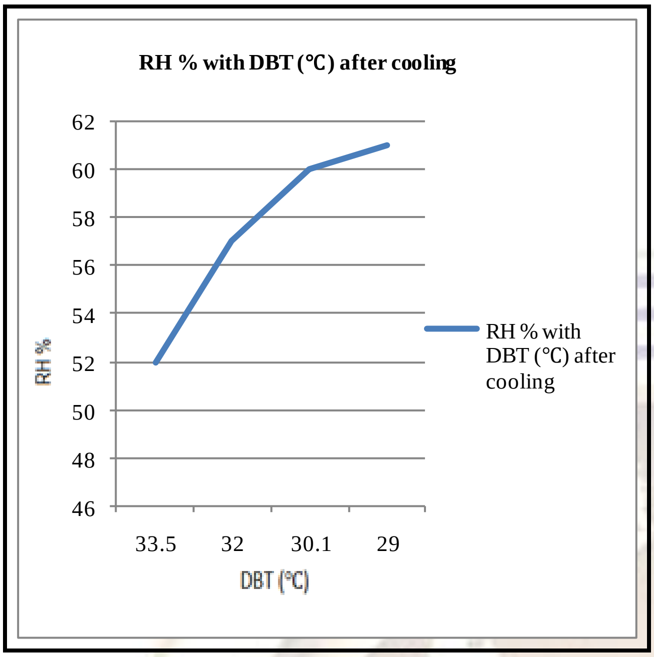
Graph 5. Between RH % after cooling and velocity (m/sec

At 04:00 pm



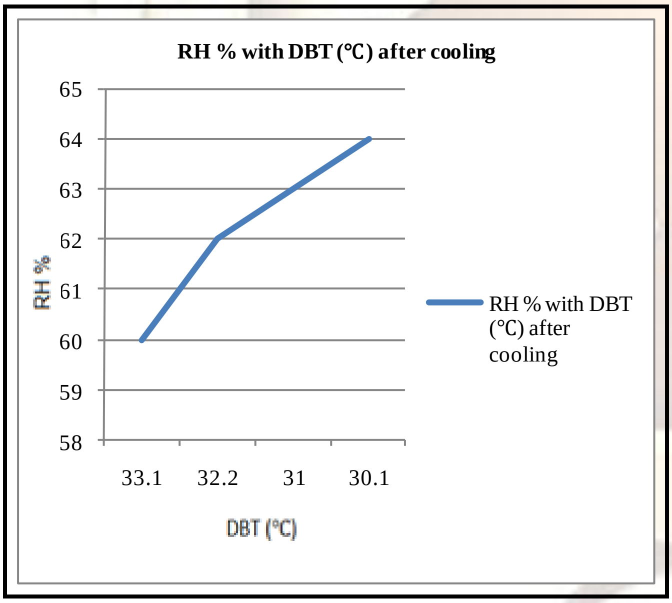
Graph 6. Between RH % after cooling and velocity (m/sec)

At 12:00 pm



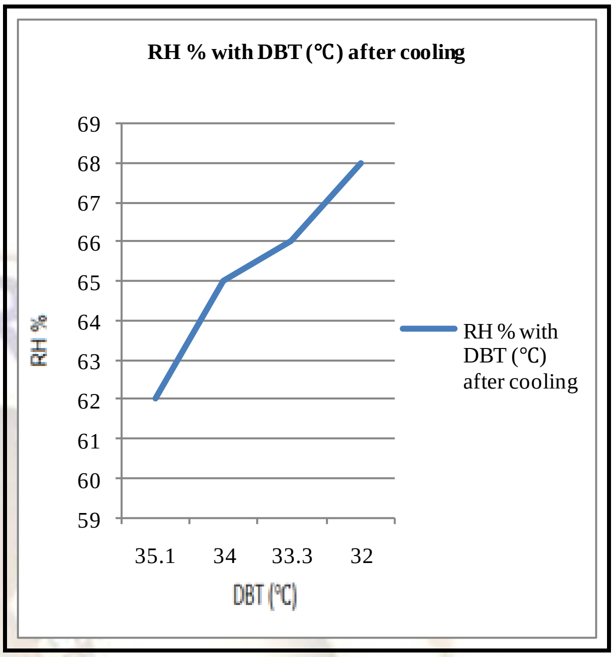
Graph 7. Between RH % and DBT (°C) after cooling

At 02:00 pm

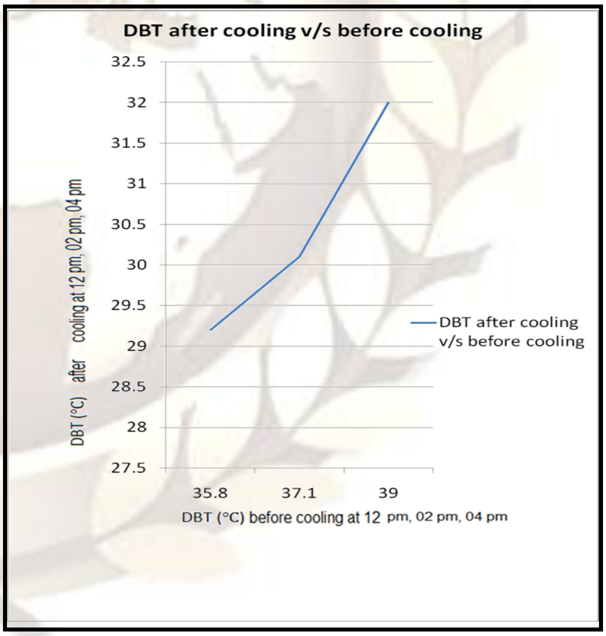


Graph 8. Between RH % with DBT (°C) after cooling

At 04:00 pm



Graph 9. Between RH % and DBT (°C) after cooling



Graph 10.

VII. EFFICIENCY MEASUREMENT

OBSERVATIONS FOR ENERGY SAVING

The table below shows the percentage of electricity, water consumption and average leaving air temperature of the cooler after analysis.

PARAMETERS	WITH PUMP	WITHOUT PUMP	% OF SAVING {(A-B)/A}*100
ELECTRICITY CONSUMPTION PER HOUR	130watt/hrs	90watt/hrs	31 %
WATER CONSUMPTION PER HOUR	5-6 litres (avg) varies with temperature	2-2.5 litres (avg) varies with temperature	55% (avg)
LEAVING AIR TEMPERATURE IN DEGREE CELCIUS	29.2	29.7	1.7% (increase)

Table 5

Economic Analysis

Design Life: - The design life of an evaporative cooler varies as a function of its design, application and especially the quality of the water. Most inexpensive coolers have an expected life of about 10 years. Ceramic pipes have durability of about 2 years.

VIII. DISCUSSION

Less expensive to install

- Estimated cost for installation is about half that of central refrigerated air conditioning. [9]

Less expensive to operate

- Estimated cost of operation is 1/4 that of refrigerated air.
- Power consumption is limited to the fan only.

Ease of Maintenance

- The only one mechanical part in our evaporative cooler is the fan motor which can be repaired at low cost and often by a mechanically inclined homeowner.

Ventilation air

- The constant and high volumetric flow rate of air through the building reduces the age-of-air in the building dramatically.
- Evaporative cooling increases humidity, which, in dry climates may improve the breathability of the air.

Power saving

- Electricity consumption is reduced due to absence of pump.

Water saving

- Less water is consumed compared to conventional evaporative cooler.

IX. CONCLUSIONS

- It has been found that by not using pump electricity consumption reduces by 31 %. It is not affected by atmospheric conditions.
- The water consumption reduces by an average of 55 %. But water consumption increases with increase in atmosphere temperature where cooler is kept.
- The average efficiency of cooler is 71.8 %.

ACKNOWLEDGMENT

I take pleasure in expressing my gratitude towards MAULANA AZAD NATIONAL INSTITUTE OF TECHNOLOGY, BHOPAL, and the institute responsible for my intellectual and academic growth. I also gratefully acknowledge the inspiring efforts of my family & friends, who constantly encouraged me to maintain the level of enthusiasm for completing this paper. I would also like to express my gratitude to all staff members of Mechanical Engineering Department, MANIT, Bhopal, for their cooperation in my work. I also indebted to those who have helped me directly or indirectly to accomplishment of this task.

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