IMPLEMENTATION OF ATMOSPHERIC WATER GENERATION BY DEHUMIDIFICATION PROCESS

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ABSTRACT: Rapid development and growth in the technology of dehumidifiers has encouraged the massive implementation of dehumidification process for drinking distilled water. Features including purification and filtration with the help of condenser, evaporator and compressor facilitates to obtain pure drinking water. In this paper, the dehumidifier model to reduce and maintain the lower humidity levels in the environment is demonstrated. The system is capable of extracting the moisture and producing a dehumidified form of water for drinking purpose by increasing occupant comfort, improving air quality and reducing the likelihood of mold, and dust mites. The performance analysis of the dehumidifier is performed on the basis of flow rate, .pressure, temperature, air humidity, efficiency of heat exchanger and cooling capacity.

INTRODUCTION

Shortage for water is the biggest concern of the 21st Century in light of the growing demand. [1]. The population growth is stressing the availability of clean water in many parts of the world. A large number of countries of the world already suffer from the drought while the deserted land and population keeps increasing. The rainfall in the areas remains broadly constant, yet the demand for clean water has twice in the last 25 years [2]. Heating, Ventilation and Air conditioning (HVAC) is a chief design that provides thermal comfort conditions for mankind. Comfort occurs only when the body temperatures are maintained within a narrow range, skin moisture and the physiological efforts of regulation are reduced normally [3]. The acceptable ranges of temperature and relative humidity are 21˚C - 28˚C and 20% -80%, respectively. In the tropical region, such as Thailand climatic zones, the conditions at 27˚C and 40% - 70% relative humidity (RH) are considered as a comfortable environment conditions [4].

Previously, various implementations of the dehumidifying conversion system have been presented and investigated [5]. Dehumidifiers are simple appliances to get rid of excessive humidity and moisture from the air. Along the surface, it appears that air conditioners and dehumidifiers are totally dissimilar from each other [6]. One is meant to cool the inside air and the other is meant to extract moisture from the air for the re-suction of the humidity. Both appliances have their very special purposes but work on the same mechanism and the principal having differences only in the internal workings [7]. Each module of the proposed dehumidifier system consists of components including: A compressor fan that can pull air inside over the units` coils. The cooling coils to cool the air, also called capillary tube or thermal expansion valve.

The condenser and evaporator collects the moisture in a container pulled from the air as shown in Fig 1. Recently, intense research initiatives have focused on the making of distilled water for drinking purpose. This project is strategically located in the village of Bujama, capital city of Lima, a deserted area, where majority have no access to clean drinking water. The project produces around 100 liters of water a day (26 gallons) that averages 83% humidity [8].

A comprehensive review is provided in [9] for the solar-driven humidification-dehumidification (HDH) desalination technology by discussing different performance parameters and psychometric coordinates. The characteristics of different layouts for the humidification dehumidification desalination process is evaluated in [10]. The major focus has been over the production and availability of the system but no research analysis has been done using the performance parameters.

In this paper, a prototype model has been proposed and demonstrated by discussing performance parameters for dehumidifying air moisture and producing a required amount of water. The model represents system that takes air as an input, then dehumidifying process starts using condenser, compressor and evaporator to obtain the filtered water as output. The paper is structured as follows, Section II discusses the principle of operation. In Section III, the dehumidification functionality has been demonstrated and output efficiency of the proposed model and Section IV summarizes the analytical results and limitations of the approach.

MATERIALS AND METHODS

Principle of Operation

Fig. 2 depicts the overall system mainly consisting of an evaporator as a dehumidifier, compressor, condenser as the regenerator, an expansion valve (capillary tube), a water tank and propeller fan. This system is referred as a heat pump type dehumidifier. The blower power is 17hp with 1800BTU capacity containing a Freon-12 refrigerant gas.

A moist air contains oxygen and water particles that make up a humid air in the environment. The compressor pumps the gas upward to the condenser in which the gas circulates. The air is cooled down at its dew point level from the expansion valve. The process maximizes the pressure level as the molecules are spread out causing the gas to be chilled.

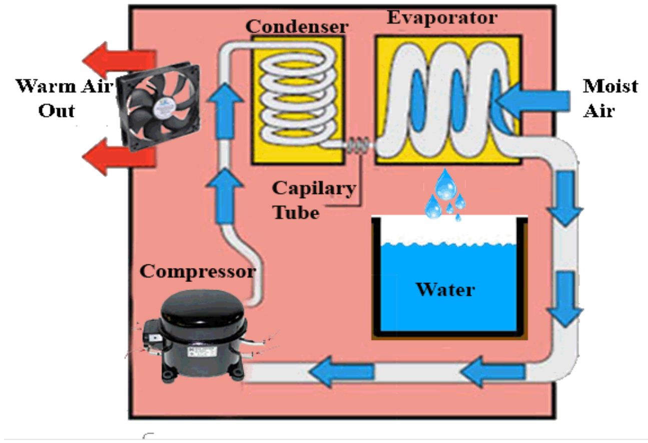

Fig. 1. Overall System Model

The water consolidates on the chilled surface of the evaporator and dribbles into a water container or is driven specifically to a channel. At that point the cool dry air proceeds through a hot condenser, which warms it up and returns to the space to get new dampness. This methodology is preceded until the desired result is accomplished.

A refrigerant dehumidifier is basically a cooling unit, where the air first passes over the evaporator for cooling and then over the condenser loop for warming purpose. The icy evaporator decreases the air temperature. The condensation formed on the cold coil drips into a bucket and the water is either drained or collected in a tank. As the encompassing air gets dried, the dew-point is brought down and the temperature that is maintained on the cool evaporator loop likewise is lowered. An evaporator coil temperature of 0°C is unlikely, that the air will be minimized much below 9°C dew-point. The air at 25°C, 60% RH already has a dew-point below 9°C. If the dew-point of the air is low, the coil temperature is necessary to create condensation equal to zero. At this level, the operating efficiency of the dehumidifier is very much minimized. The evaporator begins to freeze as the water vapor makes contact with the cooling coils surface. The most important thing to understand about a dehumidifier is that the efficiency and performance is directly related to the difference between the air dew-point temperature and air dry bulb temperature.

Dehumidifying Process

This strategy comprises in expelling dampness from the air moisture by cooling it underneath the dew point. The main elements are propeller fan, compressor and heat exchangers also known as condenser and evaporator. The propeller fan forces the flow of humid air through heat exchangers. The evaporator temperature is lower than the dew point which causes out dropping of steam that is circulating everywhere. Cooled and dried air, when passing through the evaporator, is warmed at the condenser. The temperature of air coming out of the dehumidifier is 2-9°C higher than the temperature of the sucked air. The effect of the relative humidity on the system productivity is shown in Fig. 3. Humidity is not always directly related to the temperature but it can be reduced depending on weather conditions and atmosphere. The temperature rise may cause rapid vanishing of water. The wet dividers encourages dehumidifying and does not show a sign of danger on account of dehumidifying by warming and ventilating. The volume of water contained is viably diminished alongside the development of operation in a closed room as shown in Fig 3.

Viability of dehumidifiers relies upon the working conditions, parameters and on the size of machines. It achieves its most extreme worth with higher estimations of temperature and relative moistness. The specific nature of these machines makes it impossible to use them in temperatures below 3-8°C. The moist air depends on the diameter and length of the capillary tube. The more is the drop in pressure of the refrigerant as it passes through the capillary tube, the smaller is its length and diameter.

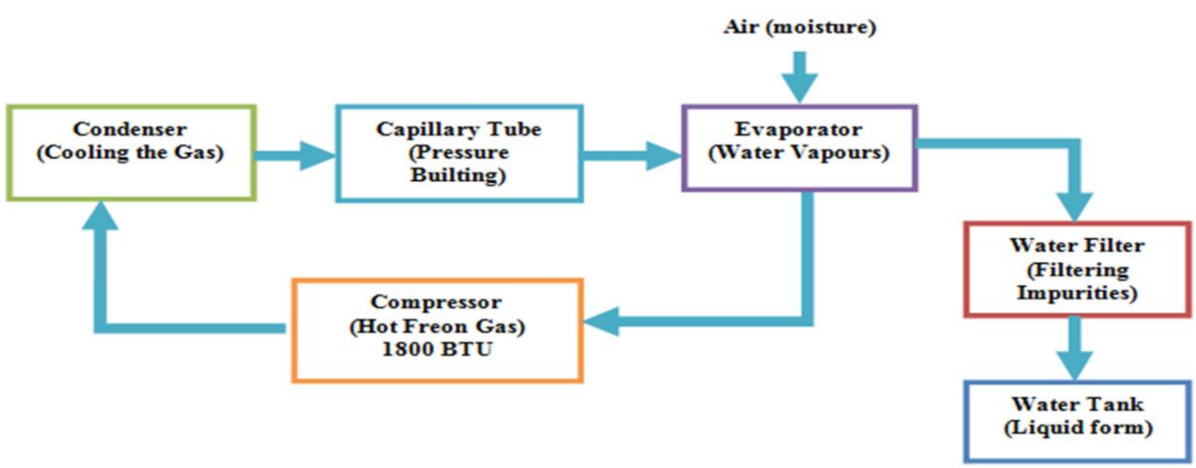

Fig.2 System Block Diagram

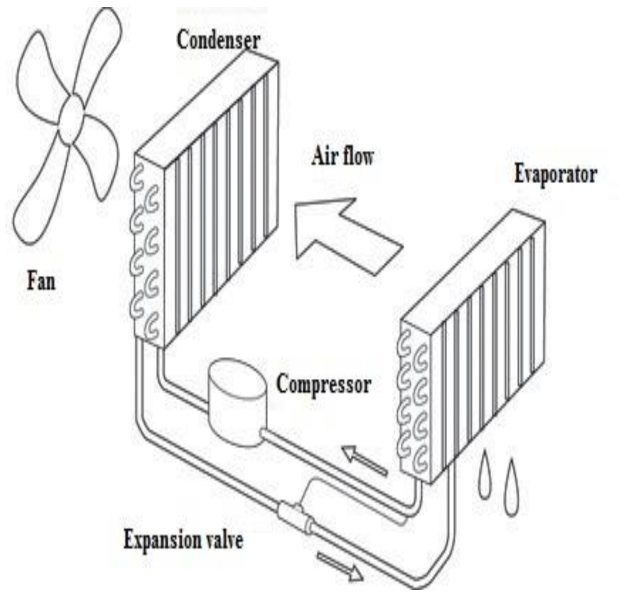

Fig. 3 Dehumidification process [10]

Psychometric Chart

If the dew point temperature of the air increases the chances of formation of dew inside the valves which can contribute to the erosion of their operation. Therefore, it is very important that the air sinking to such automatic valves should very low dew point temperature. During the heating and dehumidification process the dry bulb temperature of the air increases, however, its dew point and wet bulb temperature reduce.

On the psychometric chart, this procedure is mapped by a neat angular line starting from the given dry bulb temperature conditions and extending downwards towards right to the final dry bulb temperature conditions [11]. Psychometry is the science associated with atmospheric air mixtures, control, and the effect on materials and human comfort. Psychometric charts are graphical representations of the psychometric characteristics and properties of air. Psychometric charts allows to graphically analyze the different types of psychometric process and find solutions of many practical problems without performing long and tedious mathematical calculations.

Fig 4 depicts the dry bulb temperature increase from the left to the right. The vertical lines shown in the Fig.4 represents the constant dry bulb temperature lines. The moisture is the amount of water vapors that are present in the air and is measured in grams per kilogram of dry air which is (gm/Kg of the dry air). The moisture that is present inside the air is indicated by the vertical lines scale located towards the extreme right of the scale bar. Outermost curve along the left side of the scale indicates the Wet Bulb temperature scale.

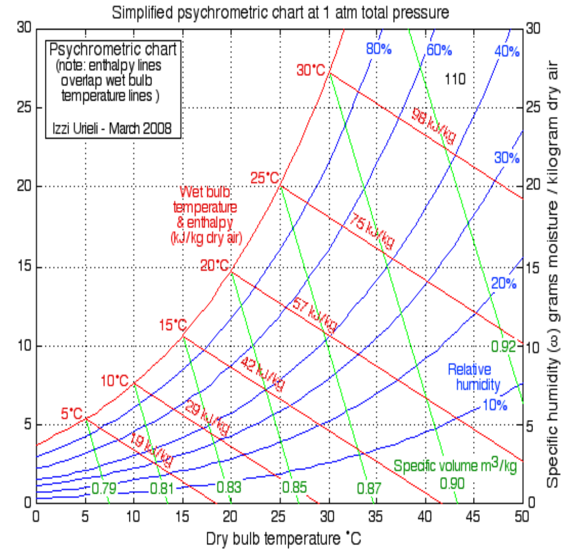

Fig. 4 Psychometric Chart [10]

The Wet Bulb temperature lines are represented by the diagonal lines that are extended from Wet Bulb temperature curved scale towards the right side of the chart. All these points that are located along the constant Wet Bulb temperature line have the same temperature. If the air is gradually cooled down while maintaining the moisture content constant, the relative humidity will rise up to 100%.

This temperature at which the air moisture saturates is called the dew point temperature. The dew point temperature of the air depends on the amount of moisture content of the air, Constant moisture lines are also constant dew point temperature lines. The equation for solving dew point temperature is [12]

$$T_{\mathrm{dp}} = \frac{237.3\ ln\left(\frac{es \times rh}{611}\right)}{7.5\ ln10 - 10\left(\frac{es \times rh}{611}\right)} \qquad (1)$$

where T_{dp} is dew point temperature, es is saturation vapor pressure and rh is relative humidity.

RESULTS

The performance of the proposed dehumidifier is verified by using the effects of parameters such as flow rate, temperature, pressure, temperature and humidity of air, the effectiveness of heat exchanger and cooling capacity. The results evaluates the system performance and efficiency for generating more distilled water for drinking purpose by dehumidification process. The Overall simulation model for dehumidifying air moisture and producing a required amount of water has been portrayed in the Fig 5.

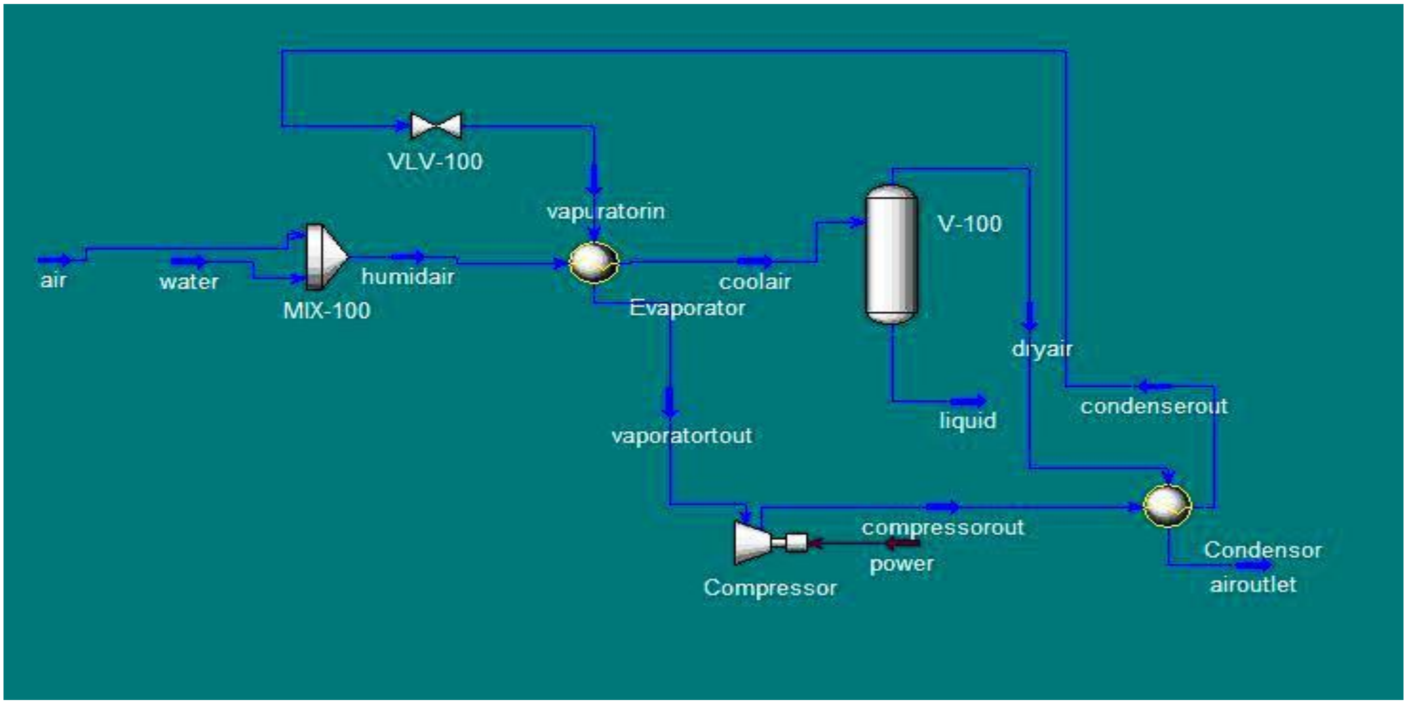

Fig.5 Overall Simulation Model

Table.1 includes temperature in Celsius (C) and humidity in terms of percentages (%). The output is mass flow, which is water and is measured in kg/h. All these reading are taken at the output where water is produced, depending on the air temperature and air humidity that varies with respect to the environment. In this proposed model, we have used the 1800 BTU capacity for the pressure building with specific atmospheric pressure at 17 psi which is equivalent to 117.2 Kpa.

Table. 1. Proposed System Model Output

S.No	Temperature C	Humidity %	Water kg/h
1	25	30	0.28
2	27	35	0.42
3	30	40	0.59
4	35	50	1.00
5	37	55	1.21
6	40	60	1.90

Table.2 shows the results which are obtained from the proposed simulation model of the dehumidifier for water generation. The table includes values obtained for temperature, humidity, grams of moisture, mass flow of water and amount of water produced. As depicted in psychometric chart and in Table 2, when the temperature rises this will cause the mass flow as they are both directly related to each other. Actual theoretical and simulation parameters are kept same in order to demonstrate our simulation and actual theoretical results.

Table. 2. Simulation Results of Proposed Model Output

S.No	Temperature C	Humidity %	Grams of moisture	Mass flow of Water in air	Water kg/h
1	10	20	3	0.25	0.1
2	25	30	6	0.50	0.33
3	27	35	8	0.66	0.47
4	30	40	10.8	0.90	0.67
5	35	50	18	1.50	1.21
6	37	55	22	1.83	1.50
7	40	60	28.7	2.39	2.01

In Table.3, the input power of 0.5257kW provided to the compressor contains 1800 BTU amount of heat with a flow rate of 1899 KJ/h. For the analysis of thermal conditions, moist air may be treated as mixture of binary water vapors and dry air. The variety of water vapor has a discriminating impact on the qualities of wet air. The variation of water vapor has a critical influence on the properties and characteristics of moist air. The moist air is considered as ideal gas where 1 BTU = 1055.05585 joules.

Table 3. Energy Stream Power and Compressor Power Input

Heat flow KJ/h	1899 KJ/h
Power Taking	0.5257kW
Refrigeration	453.9 kcal/h
Amount of Heat	Eighteen Hundred BTU

Table.4 shows graphical representation of temperature and mass flow that output will be achieved approximately 2 liters of water per hour, the mass flow kg/h with the temperature above 11°C at 195 Kpa_{atoms} pressure. The moist air that contains oxygen, CO_2, nitrogen and argon particles that makes up a humid air depends on the environment.

Table 4.Humid air Conditions

Vapour phase/Fraction	0
Temperature	11.92
Pressure Kpa	195.2
Molar Flow kgmole/h	0.1118
Mass Flow Kg/h	2.014
Molar Enthalpy(KJ/kgmole-C)	-2.85E+05
Heat Flow(KJ/h)	-3.20E+04
Vapour Pressure density g/m3	1.00E+01
Saturated vapour density g/m3	1.73E+01
Molar Entropy KJ/kgmole-C	5.02E+01

Fig. 5 shows that increase in temperature cause the mass flow as they are both directly related to each other. The temperature and the mass flow rise exponentially as shown in graph. Relative humidity and temperature are probably not directly related to each other but in some cases if dehumidification process is required in winter season than the humdity will gradually decrease and the temperature will be low according to the enviroment. The weather conditions change rapidly causing fluctuation and variations in RH and temperature. The formula to calculate the relative humidity ideally can be expressed as eq (2) [12].

$$Relative\ Humidity = \frac{actual\ vapor\ density}{saturation\ vapor\ density} x100\% \quad (2)$$

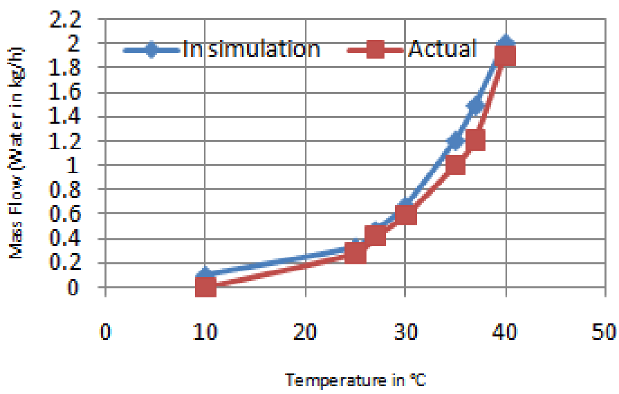

Fig. 5 Temperature and Mass Flow Graph

The units for vapor density are gm/m^3. Ideally we can calculate the relative humidity, but it varies depending upon the pressure and temperature. If the actual vapor density is 10 g/m^3 at 20°C and the saturation vapor density is kept 17.30 g/m^3, then the obtained relative humidity will be equal to 58%.

DISCUSSION AND CONCLUSION

The system introduces a solution for both drinking water and reducing the moisture level in small units including hotels, rural regions, light industry, medicine laboratories, and room servers etc. from air by Dehumidification. The proposed model consists of 7.6 Watt of propeller fan and 2.4 Watt compressor and input power which accumulates to 10 Watt. It has been observed that by using 10 Watt of solar panel having 26 cells at its surface generates 36 kJoules of energy from sunlight. In this case, a 55Ah battery is required to charge it for 12 hours to produce maximum water at maximum humidity in day time as compared to night time. The research shows that the solar dehumidification systems are much more reliable and efficient to use due to their cost effectiveness. The manufacturing and deploying cost is higher as compared to the conventional models. Using 200 units, 4.50 rupees will be charged that will consume 3KW of power consumption in 30 days (1 month) depending on usage time. The productivity of the system model increases with the growth in humidification process while the other studied parameters remain constant at certain levels. Expanding the stream rate of water, surface region of condenser or warming limit at steady estimations of the remaining parameters brings about rot in profit of the unit. Productivity will increase the performance depending on the efficiency of the parameters.

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