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Air Condensation Unit to Get Maximum Potable Water: A Review

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Abstract – Access to safe drinking water is one of the United Nations "Millennium Development Goals". Shortage of fresh water still exists in many developing countries across the globe. The shortage in fresh water supply is due to the rapid increase in population, industrialization and rapid urbanization.

Atmospheric water harvesting or atmospheric water vapor processing (AWVP) is an emerging technology in which the atmospheric water vapor is condensed and collected. Three different approaches have been considered (a) water collection on cold surfaces using either heat pump technology or radiative cooling devices, (b) concentration of the vapor using desiccants and then release the vapor in a regeneration process and (c) inducing convection currents in a tall tower structure pushing the humid air to cold high altitude zone where condensation takes place.

Vapor compression system is promising method of obtaining water from air; work on this was carried out by Mr.Abdulghani et al. at Dhahran, Saudi Arabia. They have discussed analytical & experimental methods to find out rate of condensate extraction. They have observed relation between condensate extraction rate, relative humidity& air temperature. They got maximum condensate during august month which is 99kg/day. The experimentation was carried on 1.5 ton A.C. system with simulated weather conditions at a constant volume flow rate of air of 0.135m3/s.

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INTRODUCTION

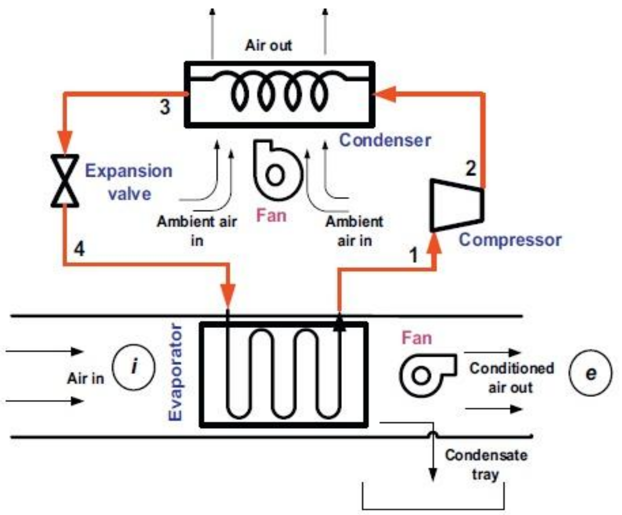
Shortage of fresh water still exists in many developing and arid countries across the globe. The shortage in fresh water supply is attributed to the rapid increase in population, industrialization and the development of urban areas. Moreover, the demand for water is high during summer seasons. However, the principle desalination methods (evaporation, reverse osmosis and electro dialysis) have been in use for over 50 years, there is still need to explore every possibility in search for new technologies or improve the present methods. Present desalination techniques consume a lot of energy that is mainly generated by burning fossil fuels, which is a depleting source and better is conserved for the future. Therefore, several universities and research centers are engaged in programs searching for new water desalination methods. A comprehensive study on innovative ideas to get potable water has been published by United Nations experts.

Significant research efforts have been made towards water obtaining from air which may be a good source. The air conditioning market is growing rapidly throughout the world. a recent published report by TechSci Research [2] indicates that the air conditioner market in Saudi Arabia is expected to growat the annual rate of 8.7% during the next five years due to its hot climate, high per capita income and rapid population growth. Therefore, Saudi Arabia becomes one of the promising places to implement the newmethod for producing freshwater from air conditioning systems. Atmospheric water harvesting or atmospheric water vapor processing (AWVP) is an emerging technology in which the atmospheric water vapor is condensed and collected. Three different approaches have been considered (a) water collection on cold surfaces using either heat pump technology or radiative cooling devices, (b) concentration of the vapor using desiccants and then release the vapor in a regeneration process and (c) inducing convection currents in a tall tower structure pushing the humid air to cold high altitude zone where condensation takes place.

Description of the setup

The base air conditioning system used for the study is a 1.5 ton, conventional split-type vapor compression system consisting of four basic components: a compressor, a condenser, an expansion valve and an evaporator connected to the air duct & a climate chamber. In an ideal cycle operation, the refrigerant mixture absorbs heat from the warm air that is passing through the evaporator and exits as a saturated vapor (state 1). When the evaporator coil surface temperature is below the dew point of the air, condensation of water vapor occurs. The refrigerant vapor is compressed to higher pressure and temperature (state 2).

The high pressure superheated vapor is cooled in the condenser by flowing air stream and exits as a liquid (state 3). The high pressure liquid refrigerant is expanded through a capillary tube where its pressure is dropped (state 4).



Basic components of a conventional vapor compression system.

The purpose of the climate chamber is to simulate and generate the actual climate conditions. The climate chamber consists of a water pump, an air blower, air and water heaters, and humidifying pads. The air heater (6 kW) is mounted at the inlet of the climate chamber to control the air temperature. A 100-literwater tank is connected to a pump for spraying water on three humidifying pads, each having a thickness of 10 cm. The pads are 10 cm apart and installed after the heater. The desired humidity of the air can be achieved by regulating the flow rate of the water and its temperature. A water heater placed inside the tank is used for heating up the water to generate air temperatures up to 50 °C and to compensate the drop of air temperature due to evaporation. The air heater and water heaters are connected to separate temperature controllers. The temperature controllers are of digital switch setting type, model: T4L-B3RK4C. The required climate conditions can be generated by controlling the temperature and humidity of the air at the same time in addition to controlling the air volumetric flow rate through the evaporator. The temperatures are measured with T-type thermocouples. Humidity and temperature sensors are connected to a data acquisition system for displaying and storing the measured data. The speed of the air is measured by a hydro-thermo anemometer of accuracy ±2%.

Photograph of the experimental set-up.

METHODOLOGY

Experiment is carried out during months of June, July, August & September, hourly climate data for these three months is collected containing information regarding temperature and relative humidity for last three years. From this data a typical hottest day with high humidity is find out and form 32 sets of climate data for constant air volumetric flow rate of 0.135m3/s.

EXPERIMENTATION

For these 32 sets of climate data, experimentally condensate extracted is find out. These experimental results were compared with an analytical method. Analytical model with engineering equation solver (EES) is used to predict the rate of condensation.

Analytical model relates cooling capacity of air conditioning system, flow rate of air, physical properties of air and refrigerant (R-22) also using isentropic efficiency of compressor -0.65.

For analytical prediction of condensate extraction, they assumed,

1) Steady state condition in system.

2) Pressure losses in refrigerant pipes are neglected.

3) Pipe heat losses are neglected.

4) Refrigerant at the outlet of evaporator and condenser are saturated.

For analysis of cooling coil, they have discussed about two approaches,

a) Contact factor & bypass factor approach &

b) Enthalpy effectiveness approach

In Contact factor & bypass factor approach – air which is directly coming in contact with cooling coil will have temperature of cooling coil, will mixed with air which is not coming in contact with coil, the mixed air will have higher temperature than cooling coil.

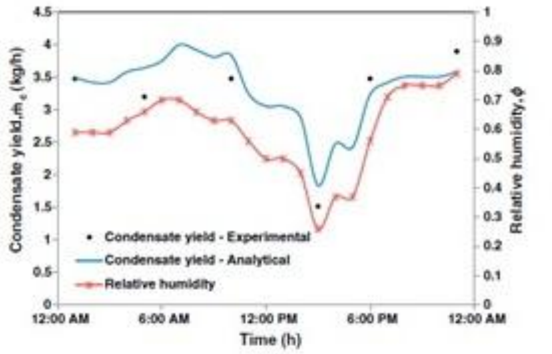
In Enthalpy effectiveness approach which is used for modeling of cooling coil, they discussed about the factors on which rate of condensate extraction depends which are humidity ratio at the exit of evaporator. The temperature & humidity of air at exit of evaporator depends on temperature of refrigerant in evaporator, its flow rate, air inlet temperature and coil configuration.

As no. of rows of coils increases, air remains in contact with coil for longer time and reducing bypass factor. Also fouling factor may reduce performance of cooling coil & hence water extraction rate.

RESULTS OF CONDENSATE EXTRACTION

The daily condensate extraction results for the summer months from June to September of Dhahran are summarized in following table.

It is observed that the condensate yield increases during the evening until the early morning hours in these months. It is also observed that the maximum hourly condensate yield occurs in August with a value of 5.1 kg during the night (8:00–10:00 PM). On the other hand, the minimum hourly condensate yield occurs during the day time with a value of 0.4 kg. Moreover, the condensate yield of the typical day of August is 83.7 kg, more than the daily average of 70.1 kg and less than the maximum daily average of 99.1 kg. The effect of relative humidity on the rate of condensate extraction for the typical day of August is shown graph below. The figure reveals that the variation trend of the condensate extraction is similar to that of the relative humidity variation, since the condensate is dominantly affected by the relative humidity. The effect of the inlet air temperature of the evaporator on the rate of condensate extraction as a function of relative humidity is shown in graph.

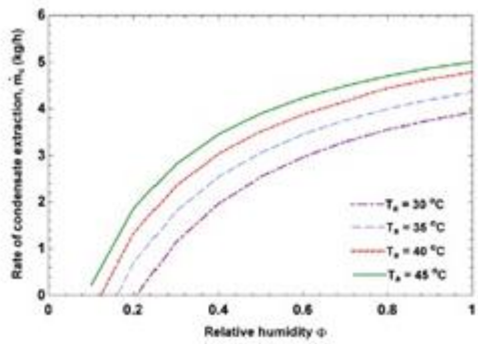


Hourly rates of condensate extraction and relative humidity for a typical day of August, Dhahran.

It is clear that the rate of condensate extraction increases with increasing the air temperature and relative humidity. The condensate increases approximately by 0.5 kg/h for every 5 °C increase in temperature. Moreover, the rate of change of condensate extraction is high in the range of 10 to 40% relative humidity and then decreases.

CONCLUSIONS

The rate of condensate extraction from the system is mainly a function of the air inlet and outlet humidity ratios and temperatures. However, the effect of the humidity ratio is more significant. The trend of the condensate extraction variation generally follows the relative humidity variation.



Rates of condensate extraction versus relative humidity for different dry bulb temperatures.

For any given relative humidity, the rate of condensate extraction increases approximately by 0.5 kg/h for every 5 °C increase in the inlet air temperature. The rate of change of condensate extraction with respect to the relative humidity is high at lower humidity and afterwards becomes lower at higher humidity. The analytical model predictions of the condensate agree well with the experimental results. The chemical analysis of the condensate indicates that the collected condensate can be used for human consumption after undergoing the required microbial processes and as an additional water source.

Since the experiment is carried out in a controlled environment with climate chamber, actual condensate extraction rate may differ when it is placed on field.There may be possibility of rate improvement of condensate if other refrigerant is used with other coil configuration.

They does not discussed about possible problem of frosting and its effects.

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