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Atmospheric Water Condensation Using Refrigeration System and Peltier Effect

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ABSTRACT

In the current scenario water shortage has become the most prevalent problem in many countries that makes it difficult to obtain water resources for drinking or other purposes. However, in humid regions, water can be generated by condensing the water vapor present in air. This project presents a method to generate a water condensation system based on thermoelectric cooling which is integrated with refrigeration cycle. The cooling compression Refrigeration system generates fresh drinking water by extracting water from humid ambient air by using Cooling Condensation process. A compressor circulates refrigerant through a condenser and an evaporator coil which cools the air surrounding it, bringing the temperature below the air's dew point and causing water to condense. Another method which is used is by using Thermoelectric cooler or the peltier cooler which works on the principle of reverse seeback effect which on provided with voltage create , one side get hot and brings heat from the cold side, leaving the cold side below the dew point which generates water . the hot side it attached to a heat sink so as to remain at ambient temperature.

INTRODUCTION

An atmospheric water generator is a device that extracts water from humid ambient air and condense to form liquid water. Water vapour present in the air is condensed by cooling the air below the dew point, or by pressurizing the air. Unlike a dehumidifier, an AWG is designed to make the water potable. AWGs are very useful in locations where portable water is in large quantity in air but difficult to obtain without condensing it,. The two primary techniques are thermoelectric cooler and refrigeration cycle method. These device uses the principle of latent heat to convert water vapour molecules into water droplets. In many countries like India, there are many places which are situated in temperate region; there are rain forest areas and even flooded areas where atmospheric humidity is eminent. But resources of water are limited. In the past few years some projects have already been done to establish the concept of air condensation as well as generation of water with the help of peltier devices, such as harvesting water for young trees using Peltier plates , this project will be helping to extend the applications of such devices further in the near future. According to previous knowledge, dew point is the temperature below which the water present in atmosphere starts to condense. Here, the goal is to obtain that specific temperature practically or experimentally to condense water with the help of some electronics devices. This project consists of a thermoelectric peltier (TEC) couple, which is used to create a temperature which is below the dew point to condense water, indeed conventional compressor and evaporator system could also be used to condense water by simply exchanging the latent heat of coolant inside the evaporator. The condensed water will be collected to use for drinking purpose and various other uses.

Peltier couple

Thermoelectric coolers are solid-state heat pumps that operate according to the Peltier effect, a theory that claims a heating or cooling effect occurs when electric current passes through two conductors. A voltage

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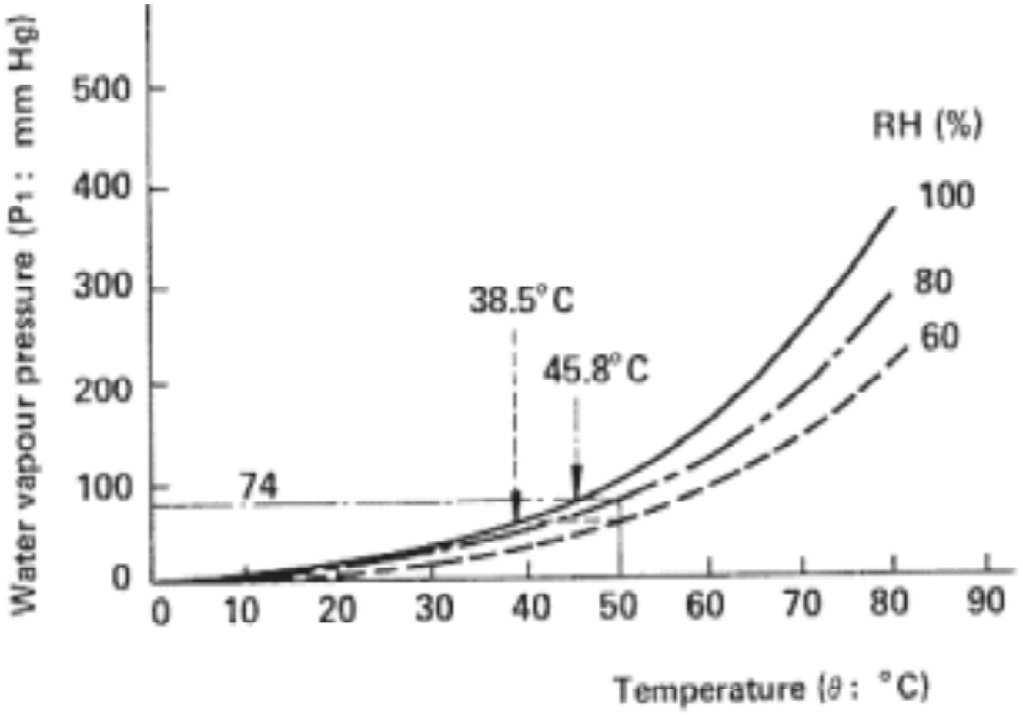


Figure 1: Dew Point on water vapor pressure curves

applied to the free ends of two dissimilar materials creates a temperature difference. With this temperature difference, Peltier cooling will cause heat to move from one end to the other. A typical thermoelectric cooler will consist of an array of p- and n- type semiconductor elements that act as the two dissimilar conductors. The array of elements is soldered between two ceramic plates, electrically in series and thermally in parallel. As a DC current passes through one or more pairs of elements from n- to p-, there is a decrease in temperature at the junction ("cold side"), resulting in the absorption of heat from the environment. The heat is carried through the cooler by electron transport and released on the opposite ("hot") side as the electrons move from a high- to low-energy state. The hot side is attached to sink to keep the hot side at ambient and cold side temperature below the dew point . Thus the air pushed into the cold side consists of water vapor condenses into liquid portable water. The dew point is the temperature to which a given parcel of humid air must be cooled, at constant barometric pressure, for water vapor to condense into water. This type of device is so powerful that it can freeze good amount of the water within several minutes.

Working Features

Practically thermoelectric couples are combined in a module, connected in order to get a promising output. Some parameters must be determined before the device under different conditions is choosed. These are:

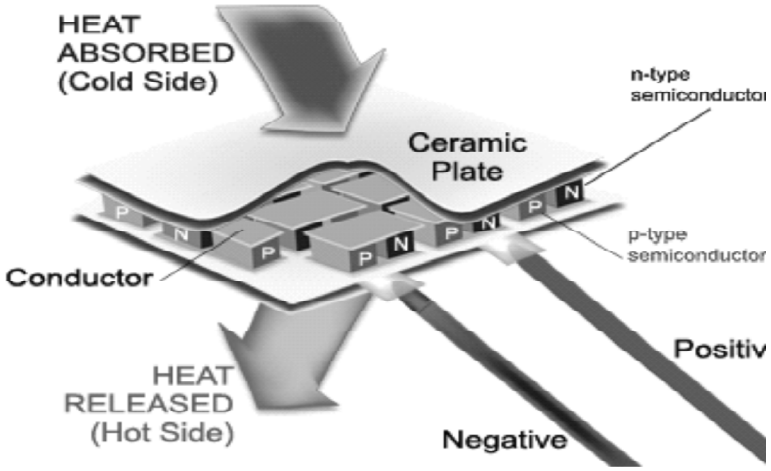
T_c: Temperature at Cold Surface.

T_h: Temperature at Hot Surface.

Q_c: The heat to be absorbed at the Cold Surface.

Now, ΔT can be defined as:

$\Delta T = T_h - T_c$

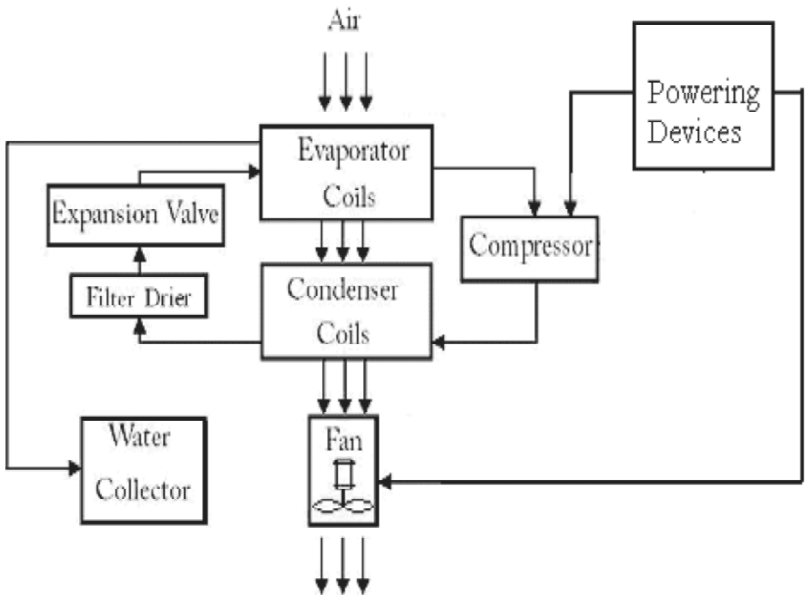


Overview of peltier device

The ratio of Q_C to H is the ratio of heat absorbed at the cold junction, to the input power i.e. Q_C / H is known as COP (coefficient of performance) which is the parameter on which the device is suppose to choose.

The performace is directly proportional to the amount of water vapor present in the humid air . the more humidity if air, the more amount of water is condensed and less amount of energy is rrquired to condense one unit of water.

Refrigeration system



The device consists of compressor which circuates the refrigerant through a condenser and through and evaporator coil which is responsible for bringing down the surrounding temperature below the dew point to condense water. the air is placed behind the evaporator coil sucks the air towards the coil. The condensed water is made to passed into a holding tank where purification and filtration system is installed to keep the water pure. The amount of water condensed is directly proportional to the relative humidity, ambient air and size of compressor. Cooling Condensation atmospheric water generators do not work efficiently when the temperature falls below 18.3°C (65°F) or the relative humidity drops below 30%.

Refrigeration cycle unit

Relative Humidity

Relative humidity is defined as the ratio of mass of the water vapor present in the unit volume of air at certain temperature to the maximum mass of the water vapor that can be accommodated in the unit volume of air when it is saturated. The partial pressure of the water vapor depends on the mass of the water vapor present in the air. Thus relative humidity also defined as the ratio of the partial pressure of the water vapor at a given temperature to the partial pressure of water vapor when the air is saturated at the same temperature. Relative humidity is a term used to describe the amount of water vapor that exists in a gaseous mixture of air and water vapor. The relative humidity of an air-water mixture is deûned as the ratio of the partial pressure of water vapor in the mixture to the saturated vapor pressure of water at a prescribed temperature. Relative humidity is normally expressed as a percentage and is calculated by using the following equation:

Required calculations and equations

The objective of the project is to condense water by obtaining the dew point temperature and by maintaining the temperature so as to minimize the amount of energy used for the production of water.the equation which relate the dew point and the tempersture of the air is given by:

B = (ln(RH / 100) + ((17.27 * T) / (237.3 + T))) / 17.27

D = (237.3 * B) / (1 - B)

where:

T = Air Temperature in Centigrade (C) degrees

RH = Relative Humidity in percent (%)

B = intermediate value (no units)

D = Dew point in Centigrade (C) degrees

Now the dew point temperature increases with increase in the relative humidity and the ambient temperature i.e. it is easier to obtain dew point temperature in humid and hot areas. TEC is typically connected side by side and sandwiched between two ceramic plates. As the number of TEC increases , the cooling ability of the device also increases. The amount of heat that can be absorbed is proportional to the current and time.

W= P.I.t

Here P is the Peltier Coefficient, I is the current, and t is time.

The coefficient of performance can b calculated as follows:

COP= Qc/Qp

Where Qc is the heat absorbed at cold surface and Qp is the total power supplied to the device.

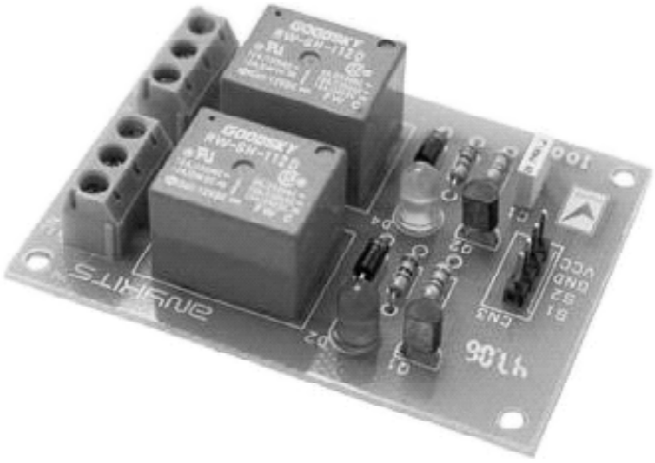
These mathematical expressions will be sufficient for this prototype project to be carried on further.

Working of the device

According to the previous elaboration, the objective is to calculate the dew point temperature D from the gathered information about that ambient environment into which the device is going to run i.e. the information regarding RH and T. Once the dew point temperature is obtained, the peltier coefficient P and the current rating of the device (TEC1) can also be obtained from device data table; thus the estimated time for generating water droplets from the humid air is calculated readily. As soon as the devices are powered, in the peltier cooler , the hot side starts getting hotter and cold side cooler; reaching the dew point temperature. The cold side of TEC starts to cool the air passing through its heat sink area and water vapors start to condense just like the water condensation happens outside a glass full of ice. In the case of refrigeration cycle method, when the air ambient air comes in contact with the evaporator , the air surrounding it , cools down below the dew down and starts to precipitate.

Level Controller

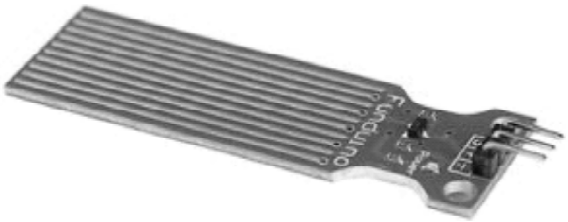
Relay circuit is used to control the ON and OFF the process depending upon the amount of water collected in the container from both the devices.



Relay Circuit Board

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principle method can also be employed which includes solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

A level sensor is used to measure the amount of water collected in the container. The level sensor is connected to an arduino which, based on the level sensor output provides signals to the relay for the switching ON and OFF of the process.



Water Level Detector

Components used in the project

The power supply uses smps (switching mode power supply) as output of 12 V evidently which is able to supply enough power to keep running two 70 W Peltier coolers connected in parallel. The Peltier device has a dimension of 4x4x0.8 cm. The maximum temperature difference i.e. ÄT of 80°C. Two 700 rpm, 6x6cm (size of TEC1) fans that are capable of producing airflow for circulation of the air. The heat sinks are made of aluminium. Activated carbon filter can be used for water filtration. An air duct is provided that throws out the cool dry air from the cooler side to the hotter side of the peltier cooler in order to maintain the temperature difference. A small box is kept for collecting the water.

Applications

There are hardly any chances to refuse that this device is portable for its simple design and endurance capability. So, the Atmospheric Water Generator is the device which can be implemented for extreme situation, to use during flood, in desert areas, and in rural areas. It has great advantages as it works like a renewable source of atmosphere water and doesn't need a heavy power source. Many companies like 'Watermaker India ltd', 'Aerowater', etc have already this type of device for domestic purposes but it is not very common in India. It can be implemented in humid areas such as Chennai, Mumbai, Kolkata etc. where the water is a matter of crisis. Our project can be helpful in such areas.

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