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(54) **Title:**
EXTENDED ATMOSPHERIC WATER HARVESTING MODULE

(57) **Abstract:**
EXTENDED ATMOSPHERIC WATER HARVESTING MODULE ABSTRACT An atmospheric water harvesting system to harvest high-quality potable water from the ambient air by way of a condensation cycle over an extended temperature range as low as 5°C (41°F) through an air energizing unit that mixes and energizes ambient air. The system utilizes sensors to monitor and predictively respond to multiple parameters, and efficiently adjusts system operation to maximize water production capability. Figure 1

EXTENDED ATMOSPHERIC WATER HARVESTING MODULE

ABSTRACT

An atmospheric water harvesting system to harvest high-quality potable water from the ambient air by way of a condensation cycle over an extended temperature range as low as 5°C (41°F) through an air energizing unit that mixes and energizes ambient air. The system utilizes sensors to monitor and predictively respond to multiple parameters, and efficiently adjusts system operation to maximize water production capability.

Figure 1

EXTENDED ATMOSPHERIC WATER HARVESTING MODULE

TECHNICAL FIELD

The present disclosure relates generally to harvesting of atmospheric water. More particularly, it relates to a system, an apparatus and a method for obtaining potable water by harvesting atmospheric water.

BACKGROUND

In recent years, global concerns regarding insufficient fresh water sources have increased greatly. In the past, people searched for locations to settle wherever freshwater sources were conveniently available through lakes, rivers, and artesian wells. As the earth population increased, water-rich land became overcrowded and eventually communities had to settle in regions of limited fresh water resources. Unfortunately, these fresh water sources are not sustainable as they are declining both in capacity and purity at alarming rates due to expansion of deserts and human population. Furthermore, factors such as climate changes, environmental pollution, as well as population growth further threaten existing fresh water sources.

Besides having insufficient fresh water sources, there are also problems associated with provision of potable water. The provision of potable water is a serious problem in areas where rainfall is scarce, seasonal, or where there are relatively small water catchment areas and little natural local water storage. Additionally, as fresh water sources are not evenly distributed globally, some geographical locations do not have ready access to fresh water. Constructing reservoirs and water desalination plants usually alleviates this problem. However, many countries are unable to afford water desalination plants due to the relatively high capital investment and operational costs required.
The atmosphere is primarily composed of nitrogen and oxygen. In dry air, these gases comprise about 78% and 21% of the atmosphere, respectively, by volume, leaving about 1% for all other gases, including argon, carbon dioxide, and ozone. However, the

atmosphere is not completely dry; it typically contains 0 to 4% water vapor, concentrated near the earth's surface.

Water vapor is simply water (H_2O) in its invisible gaseous form. It readily exists in the Earth's atmosphere at temperatures cooler than the boiling point of water, even at temperatures below freezing. Water vapor is removed from air primarily by condensation, and added to air primarily by evaporation and transpiration.

Various attempts have been made to provide systems for dehumidifying air moisture and purifying the water produced in such systems for drinking purposes. Water vapour will only condense onto another surface when that surface is cooler than the dew point temperature, or when the water vapour equilibrium in air has been exceeded. When water vapour condenses onto a surface, a net warming occurs on that surface. The process causes the release of thermal energy.

In principle, existing commercial water production systems collect water droplets formed by condensation of water vapour present in the atmosphere on cold surfaces cooled by refrigeration means which may include a compressor, evaporator, fan, condenser and a reservoir system. The system may also function as a dehumidifier and an air purifier.

The working principle is similar to the disclosure in patents filed by Ehrlich in 1978 (U.S. Pat. No. 4,255,937), Reidy in 1992 and 1993 (U.S. Pat. No. 5,106,512, U.S. Pat. No. 5,149,446, U.S. Pat. No. 5,203,989) and Morgen et al. in 2002 (U.S. Pat. No. 6,931 ,756B2). With the advent of more efficient refrigeration techniques, the cost of electricity needed for extracting an amount of water from the atmosphere can be lower than the price of a bottled water of equivalent volume, or that of the utility charge of obtaining an equivalent volume of water from the tap with the additional cost for boiling or purifying water using mechanical and chemical filtering means.

However, the hardware cost of a commercial water production system comprising compressor, condenser, evaporator and filtration means remains relatively high, leading to unattractive return of investment. Additionally, for climates with low ambient temperature levels or where temperature fluctuates significantly, atmospheric water extraction becomes difficult. Typically, these commercial water production systems for water vapour extraction operate above 23°C and above a relative humidity of 35%.

Swanson in US Pat No. 3,675,442 discloses an atmospheric water collector, which employs a cooling coil immersed in a fresh water bath in order to cool the bath. The cooled water is pumped through a conduit and condensing frame. Water vapour present in winds that pass over the condensing frame is condensed and drained into a collector. However, the cooled water is periodically mixed with the condensed water, subjecting the condensed water to contamination.

Hull in U.S. Pat. No. 5,056,593 discloses, in several variations, the use of electrostatic and magnetic fields to substantially enhance water product extraction yields in a dehumidifying heat exchanger apparatus. Liquid water droplets are electrostatically collected on grounded or charged heat transfer tubes in the heat exchanger apparatus. In one variation, charged or grounded horizontally-declined heat transfer tubes with attached drainage wicks attract liquid droplets and accelerate condensing heat transfer by continuous absorption and transfer of condensate. The use of drainage wicks to absorb and confine condensate collected on the surfaces of the heat transfer tubes may result in the loss of water extracted and advance the growth of fungi and bacteria on the drainage wicks. Additionally, the heat exchanger apparatus may be electrically unsafe with charged electrode wires entrenched between the tubes of the heat exchange unit.

Hutchinson in U.S. Pat. No. 7,000,410 discloses a device that utilizes a condenser type refrigerant system with multiple fans and two air chambers to produce water from the air. The apparatus further deploys a stainless steel ioniser to charge the ambient air to maximise extraction of moisture from the air. The two air chambers operate in tandem to mix desiccated ionised air that exited from the evaporator plates with fresh incoming air drawn through a compressor, a condenser and the ioniser. This causes partial drying of the newly formed condensation, which results in loss of condensation leading to reduced output and efficiency.

Katsumi in JP Pat. No. 02,172,587 and Han in U.S. Pat. No. 5,435,151 disclose water making apparatus for use on vehicles. Engel et al. U.S. Pat. App. No. 20040040322 discloses a similar water extraction device for vehicles, together with some applications including central air system and mobile unit. All the disclosed devices tap on existing or external air conditioning systems to simplify system design and lower device cost. However, conventional designs fail to function properly in many temperate areas where ambient temperature drops below 20°C during the night or during cold spells and storms. This problem accentuates for water extraction devices installed on vessels and ships, on caravans and emergency vehicles.

LeBleu in U.S. Pat. No 5,669,221 describes a water generating apparatus in which moisture from ambient air condenses to form sterilized water. However, such an apparatus uses a dedicated heating strip to heat up the ambient air, a secondary heat absorber to produce cold sterilized water and an electric heater to heat up hot sterilized water.

Engel in U.S. Pat. No. 6,755,037 describes a water generating apparatus using moisture from ambient air as a source for providing air conditioning and dehumidification. However, this apparatus requires use of physically and functionally separate and independent components to produce hot/cold sterilized water. In addition, the air conditioning function and the apparatus operate spatially away from one another.

James J Reidy in U.S. Pat. No. 5,106,512 and 5,149,446 describes a water generating device having a fan for moving air over a condensing unit (evaporator coils), a collection point to catch water falling off the condensing unit, a water reservoir and various treatment options. The device is a single location unit and primarily relates to a single use filter element.

Auqatronics Inc. in U.S. Pat. No. 6,588,226 describes a water recovery and dispensing system for use in situation of low temperature and/or low humidities, where there is either a low water vapour level (and thus little water to condense from the air) or where there is potential small temperature differential and thus more difficult dew point temperatures to deal with. Similar to U.S Pat. No. 5,106,512 and U.S Pat No. 5,149,446 described above, the system also uses a fan to move air over a condensing unit (evaporator coils) but with a control system that permits and indeed, promotes the build up of ice on thereon.

There are a number of water generating devices described in the prior art which employ conventional dehumidification process for removing water from the air for collection into a storage tank. Many of such devices also employ various types of water and air filtration systems to create water that is safe for consumption. While current water generating devices may operate satisfactorily indoors at room temperature conditions, they are not particularly conducive for use outdoor at cooler temperature in the range of 10°C to 22°C (50°F to 71.6°F) frequently encountered in temperate climates. The prior art devices commonly use a typical refrigerant deicer system to keep their evaporators from freezing under low condensate flow rates, which can occur with cool ambient air. The units usually use large capacity refrigerant gas dehumidifiers (compressors). The refrigerant gas from a compressor cools an evaporator coil and when ambient air passes through the coil, moisture condenses out and drips to a water collector below. When operated over extended periods or in cooler temperatures, the evaporator tends to freeze over due to low flow rate of condensate. Some have overcome this problem by switching over to a hot-gas bypass mode. A thermostat and/or humidistat control assists in determining when the compressor switches over. When the temperature of the incoming air is too low, this on/off cycle during cooler temperatures drastically reduces water production rate. Much of the above mentioned prior art is limited in functionality and scope in performing efficient air to water conversion, thereby exhibiting an undesirable shortcoming and inability to efficiently convert moisture in the air into water of any quantity near to the total amount of water vapour actually present in the atmosphere.

Therefore, there is a need for a system and a method for obtaining potable water by harvesting atmospheric water, which at least addresses one of the aforementioned disadvantages.

SUMMARY

One aspect of this disclosure describes a water harvesting system for obtaining potable water from ambient air, wherein the potable water includes water droplets, wherein the ambient air comprises water vapour, wherein the ambient air is characterized by a temperature and a relative humidity level. The system comprises an ambient air intake means adapted to receive a supply of ambient air and adapted to convey received ambient air along an air travel path. The system also comprises an air energizing means disposed along the air travel path. The air energizing means adapted to increase the temperature of the received ambient air to produce energized ambient air, wherein the energized ambient air comprises water vapour. The system further comprises a condenser means disposed along the air travel path. The condenser means having at least one surface adapted to extract water from the energized ambient air that is exposed to the at least one surface of the condenser means, wherein the at least one surface of the condenser means has a temperature that is lower than that of the energized ambient air. The air energizing means comprises a first surface area and the condenser means comprises a second surface area. Furthermore, the ratio of the first surface area to the second surface area is 0.6 : 1.

In another aspect of this disclosure, a water harvesting apparatus is described. The apparatus comprises an ambient air intake device, an air energizer and a condenser. The air energizer is disposed in the periphery of the ambient air intake device.

In yet a further aspect of this disclosure, a method of harvesting potable water from ambient air is described. The ambient air is characterized by a temperature and a relative humidity level. The method comprises, exposing the ambient air to an air energizing means, increasing the temperature of the ambient air by way of the air energizing means, channeling the ambient air for thermal interaction with a condenser means and extracting water from the ambient air.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following description, details are provided to describe the embodiments of the application. It shall be apparent to one skilled in the art, however, that the embodiments may be practised without such details.

Embodiments of the disclosure are described hereinafter with reference to the following drawings, in which:

Figure 1 shows a partial schematic diagram of an atmospheric water harvesting apparatus according to an embodiment in this disclosure;

Figure 2 shows a water production test data sheet;

Figure 3a shows a front perspective view of the atmospheric water harvesting apparatus according to an embodiment in this disclosure;

Figure 3b shows a side perspective view of the atmospheric water harvesting apparatus according to an embodiment in this disclosure;

Figure 3c shows a back perspective view of the atmospheric water harvesting apparatus according to an embodiment in this disclosure; and

Figure 4 shows an operational flow of the atmospheric water harvesting apparatus of Figure 1 and Figures 3a-3c.

DETAILED DESCRIPTION

With reference to the drawings, embodiments of a process, a system and an apparatus according to embodiments of this disclosure for harvesting atmospheric water are described hereinafter for harvesting moisture from ambient air to produce water.

More particularly, this disclosure describes a water harvesting system for obtaining potable water from ambient air. In various embodiments, the water harvesting system includes an air energizing means adapted to increase the ambient air temperature to produce energized ambient air.

An apparatus of water harvesting is also disclosed. In some embodiments, the apparatus includes an ambient air intake device, an air energizer and a condenser.

Furthermore, a method of harvesting potable water from ambient air is disclosed. By exposing the ambient air to an air energizing means, the ambient air temperature can be increased and this can optimize the rate of water harvesting.

For the purposes of brevity and clarity, the description herein is limited to applications related to atmospheric water harvesting. This, however, does not preclude various embodiments of this disclosure from other applications that require similar structural designs and/or similar operating performance. The fundamental operational and functional principles of the embodiments of this disclosure are common throughout the various embodiments for harvesting atmospheric water. Embodiments described herein are suitable for operating at temperatures of approximately 5°C and above.

An embodiment of the disclosure described in the detailed description provided hereinafter is in accordance with Figure 1, Figure 3a-3c and Figure 4 of the drawings, in which like elements are numbered with like reference numerals.

Figure 1 shows an atmospheric water harvesting system 100 (hereinafter known as system 100) for obtaining potable water from ambient air according to an embodiment of this disclosure. In this disclosure, potable water includes water droplets, and the ambient air comprises water vapour. The ambient air can include a temperature and a humidity level. The system 100 generally comprises a harvesting unit 110 or a housing, a channeling passage 111, and a refrigerant source 138. In some embodiments, the system 100 is a modular system where the harvesting unit 110 can be coupled to any separate or existing apparatus. In some other embodiments, the system 100 can be configured to function as a stand alone entity.

The harvesting unit 110 comprises an ambient air intake means 112 and an exhaust 114 formed therein for allowing flow of the ambient air therethrough. The ambient air intake means 112 can include a device, a structure and an apparatus adapted to receive and regulate a supply of ambient air. Examples of ambient air intake means 112 include openings or vents and in some embodiments, at least one ventilator can be disposed on a side of the openings or vents. The ambient air intake means 112 can be adapted to convey the received ambient air along an air travel path.

The harvesting unit 110 can further comprise an air energizer 116 or air energizing means, a heat dissipating unit 120 and a condenser 118 or a condenser means, in which the condenser 118 is disposed between the air energizer 116 and the heat dissipating unit 120. Depending upon embodiment details, the harvesting unit 110 can comprise an air filter 124 or an air filtering means and a water collection pan 128 or reservoir.

The air energizer 116 and the condenser 118 can be characterized by their respective surface area. In some embodiments, the surface area ratio of the air energizer 116 to the condenser 118 is approximately 0.5 - 0.8 : 0.8 – 1.2. In some representative embodiments, the surface area ratio of the air energizer 116 to the condenser 118 is 0.6 : 1.

The air energizer 116 can be a receptacle, a column, a device, a structure or an apparatus adapted to increase the temperature of the received ambient air to produce energized ambient air, which comprises water vapour. Temperature increments can be predetermined, controlled and/or varied by user input by way of switches, buttons, and/or control knobs. Computers or some other microcontroller based devices can also be used to increase the temperature of the received ambient air. In some embodiments, the temperature increment is automatic in response to external factor(s) including temperature of the ambient air, humidity of the ambient air and/or weather conditions. To maximize the rate of water harvesting, the air energizer 116 is disposed approximately 1 – 2 cm away from the condenser. This can maximize energized air thermal interaction with the condenser 118 before the energized air loses energy and this in turn, maximizes the rate of water harvesting. The air energizer 116 can be an extension of the heat dissipating unit 120 formed using tubes which receives hot refrigerant from the heat dissipating unit 120. As such, no additional electrical means will be required to power the air energizer 116. In U.S Pat. No. 5,669,221, a heating element powered by electrical means is utilized to provide similar energizing effects. One drawback is that due to the heat generated by the electrical element, the moisture in the air dries up and that reduces the water harvesting efficiency. The air energizer 116 can be disposed in the periphery of the air intake means 112 and along the air travel path.

In accordance with some representative embodiments of this disclosure, the heat dissipating unit 120 is configured to cool refrigerant. The heat dissipating unit 120 can comprise coiled type elements having a plurality of coils, optimized to increase the rate of water harvesting. Further details are discussed below.

The condenser 118 can be a receptacle, a column, a device, a structure or an apparatus adapted to extract water from the energized ambient air that is exposed to a surface of the condenser 118. For simplicity, embodiments of the condenser 118 described herein have a surface. However, it should be understood that the condenser 118 can have more than one surface. Having a condenser 118, which in some embodiments comprises twelve to fourteen surfaces per square inch of surface area, can maximize the air thermal interaction with the surfaces and thereby maximizes the rate of water harvesting. In this respect and depending on the configuration of the water harvesting system, the condenser 118 can comprise coiled type elements having a plurality of coils, optimized to increase the rate of water harvesting.

Figure 2 shows a water production test data sheet in relation to some embodiments of this disclosure. In Figure 2, information including ambient air temperature, ambient air relative humidity, ratio of the height of air energizer 116 to condenser 118 and ratio of the size of condenser 118 to heat dissipating unit 120 are shown. For clarity, the ratio of the size of condenser 118 to heat dissipating unit 120 can also be interpreted as the ratio of the available heat transfer area of the coils of the condenser 118 to the coils of the heat dissipating unit 120. In some embodiments, the ratio of the available heat transfer area of the coils of the condenser 118 to the coils of the heat dissipating unit 120 can be approximately 0.25 – 1 : 1. For example, the ratio can be approximately 0.75 : 1. According to various embodiments in this disclosure, the coils of the condenser 118 and the heat dissipating unit 120 are formed from cylindrical tubes of approximately 0.5 – 0.8 mm in diameter per tube. In some representative embodiments, the cylindrical tubes are 0.7 mm in diameter per tube. Using tubes of such dimensions can provide higher heat exchange efficiency. This is due to the substantially greater heat transfer area that is a result of more tubes being packed within the condenser 118 as compared to using tubes of bigger sizes.

The air filter 124 can be a device, a structure or an apparatus adapted to filter the ambient air. The air filter 124 can comprise mesh filter, electro-static filter, activated carbon form, HEPA filter or any other form(s) known in the art.

When the air energizer 116 energizes the ambient air, it increases the internal energy of the ambient air by approximately 3°C to 15°C which in turn uplifts the dew point of the energized ambient air for enhancing condensation of water vapour thereto. According to some representative embodiments, the ambient air is increased by approximately 5°C to 10°C. The air energizer 116 can also be configured to prevent condensate from freezing on the surface of the condenser 118, thereby extending the operating temperature range and allowing embodiments of the present disclosure to continue operation at approximately 10°C below ambient temperatures. This feature is particularly desirable for use in environments with low outdoor temperatures, where freezing of the condensating surface presents a problem. Some existing systems are designed to only produce water in an air-conditioned environment. That is, such ambient temperatures are generally in the range 24°C — 30°C, with relative humidity levels of about 30% and above. However, in outdoor settings, where substantially cooler ambient temperatures may be as low as 5°C, the condensating surface temperature of around 10°C will generally freeze. Some prior attempts to prevent such freezing include disposing heating strips adjacent to the condensating unit. This in turn dries up the moisture in the air and consumes more electricity. Depending upon embodiment details, the air energizer 116 can also be adapted for suppressing the undesired growth of mold and algae on the surface of the condenser 118 by drying up water droplets on the surface of the condenser 118 when the system is not in use.

The condenser 118 comprises a surface for condensing water vapour in the energized ambient air to obtain water droplets. The surface of the condenser 118 can have a lower surface temperature than the energized ambient air. One feature of at least some of the embodiments is that the energized ambient air is transportable for thermal interaction with the condenser 118 for condensation of water vapour to take place. Condensation of water vapour occurs when a surface is colder than the dew point temperature of the air surrounding the surface. At this temperature, the air has a relative humidity equivalent to 100 percent and the air becomes saturated with water. The dew point temperature of the air is dependent on both air temperature and humidity levels. Therefore, the surface of the condenser 118 over which the energized ambient air flows must have a temperature that is lower than the dew point temperature of the energized ambient air.

The channeling passage 111 is inter-configured for cyclical or non cyclical passage of refrigerant therethrough. The channeling passage 111 comprises an inlet channel 130 or first channeling passage, a second channeling passage 132, a third channeling passage 134 and a return channel 136 or fourth channeling passage. The inlet channel 130 is for receiving warm or hot refrigerant from the refrigerant source 138 and the return channel 136 which couples the condenser 118 to the refrigerant source 138 is for returning cooled refrigerant to the refrigerant source 138. In some embodiments, the second channeling passage 132 couples the air energizer 116 to the heat dissipating unit 120. The third channeling passage 134 can couple the heat dissipating unit 120 to the condenser 118.

The air energizer 116 is in thermal communication with hot refrigerant from the refrigerant source 138 via inlet channel 130 and is also in thermal communication with the ambient air. The hot refrigerant, by way of the second channeling passage 132, is then in thermal communication with the heat dissipating unit 120 to further radiate the heat built up in the hot refrigerant to cool the hot refrigerant. Depending upon embodiment details, the heat dissipating unit 120 can comprise switches, buttons or control knobs for controlling and/or varying the temperature to which the hot refrigerant is to be cooled.

Alternatively, the controlling and/or varying of the temperature can be done by way of a computer or any other microcontroller based devices. The partially cooled refrigerant is then transportable by way of the third channeling passage 134 to the condenser 118 for cooling the surface of the condenser 118 to a temperature that is lower than the dew point temperature of the air surrounding the surface of the condenser 118 for condensation of water vapour to occur. The surface of the condenser 118 can be made of any material which water vapour condensation can occur in response to cooling of the material in a given environment. For instance, the material can comprise copper, zinc, bronze, gold, silver, metal alloy, or the like. An outlet of the condenser 118 is in communication with the return channel 136 which directs cooled refrigerant back to refrigerant source 138.

The surface of the condenser 118 can be film-coated with food-grade materials, such as, gold, tin, Teflon or the like in compliance with public health requirements governing use of materials in contact with drinking water. Additionally, the surface of the condenser 118 can be plated with gold or any material which enhances the rate of heat transfer. The condenser 118 is preferably designed for optimising air circulation, velocity and distribution of air on the surface for achieving an optimal rate of water vapour harvesting. The system 100 also comprises an actuator valve 140 coupled to the refrigerant source 138 for controlling the supply of or displacing refrigerant from the refrigerant source 138 into the harvesting unit 110 via the inlet channel 130. The actuator valve 140 can also be configured to regulate the supply of refrigerant. The refrigerant source 138 can comprise a refrigerant, such as Freon, or any other refrigerants used in existing refrigeration systems that can supply sufficient amount of refrigerant to chill the surface of the condenser 118 to a temperature below the corresponding dew point temperature.

Prior to energizing of the ambient air by the air energizer 116, the ambient air can be passed through the air filter 124 of the harvesting unit 110. The air filter 124 is for filtering the ambient air and is disposed in the vicinity of the air energizer 116. The air filter 124 can also be disposed on the ambient air intake means 112 or in the vicinity of the ambient air intake means 112. Furthermore, the air filter 124 is replaceable and therefore can be replaced when necessary.

A ventilator 126, is disposed in the vicinity of the heat dissipating unit 120 and is for displacing and/or directing the ambient air into the harvesting unit 110. The ventilator 126 can be an impeller-based air mover or fan or other type of device, structure or apparatus controllable to vary volume and flow of the ambient air under multiple parameters across the condenser 118, thereby cooling the atmospheric air and condensating the water vapour into water droplets. By varying the volume and/or flow of ambient air, convecting air currents necessary for obtaining sufficient water vapour condensation on the surface of the condenser 118 are generatable. The ventilator 126 can also be disposed on or in the vicinity of the exhaust 114. The air filter 124 and the ventilator 126 can be orientable or disposed in a manner that is readily recognised by those skilled in the art to achieve effectively clean or dust-controlled airflow or circulation inside the harvesting unit 110.

A vibrating actuator 122 is disposed in the vicinity of the condenser 118. In some embodiments, the vibrating actuator 122 is disposed on the condenser 118. The vibrating actuator 122 is adapted for increasing the effective surface area of the condenser 118 for water condensation to optimize the yield of condensed water. The vibrating actuator 122 is preferably an electric-ruggedized-rotor based actuator that is activated periodically during water harvesting phase to provide a subtle quivering effect, caused by the rotation of the rotor, on the condenser 118 to expedite the water trickling speed on the surface of the condenser 118, thereby allowing the surface of the condenser portion to be re-conditioned for condensing water vapour in the air into water droplets. Furthermore, the quivering effect, caused by the rotation of the rotor, enhances or maximizes the thermal interaction of the vapourized cooled refrigerant flowing through the condenser 118. This can provide greater heat exchange efficiency to the condenser 118 and as a result, maximize the rate of water harvesting.

The water collection pan 128 of the harvesting unit 110 is for receiving water droplets from the condenser 118. The water collection pan 128 is disposed in the vicinity of the condenser 118 such that the water droplets received can be transported to a storage area (not shown) which can incorporate a water level measurement device for measuring the water level present in the storage area to deactivate or control the water harvesting process. The deactivation or control of the water harvesting process can be automatic or in response to user inputs. Deactivation or control of the water harvesting process can be done by way of switches, buttons, control knobs and in some embodiments, the deactivation or control can be operated by a computer or some other microcontroller based devices.

The system 100 further comprises a temperature measurement device 142 for measuring or determining ambient air temperature and a relative humidity measurement device 144 for measuring or determining relative humidity of the ambient air. Additionally, the system 100 further comprises a controller 148 for controlling the system 100. The controller 148 is couplable to a signalling interface module for relaying any control signals for operating any electrically or mechanically driven parts and components of the system 100 that require instructions, signalling and/or electricity supply.

The controller 148 preferably comprises a microprocessor (not shown) for storing and executing software applications or embedded codes which are capable of generating appropriate control signals in accordance with a set of preprogrammed or predetermined instructions. Measured data obtained from the temperature measurement device 142 and/or the relative humidity measurement device 144 can be further processed by the controller 148. Some representative processes include logging, reading and writing, storing and backing-up, analysing and displaying of measured and/or controlled data. Additionally, the controller 148 can be coupled to external computing equipment via a wired or wireless data exchange interface (not shown). Electrical power supplied to the controller 148 and the system 100 may be single-phase or multi-phase alternating current tapped from power grids or mobile electricity generators such as those used on vessels, cruises, caravans, oil rigs, construction sites and other similar facilities. Alternatively, electrical power can be supplied as direct current.

Figures 3a, 3b and 3c illustrate front, side and back perspective views of the system 100 for harvesting atmospheric water from ambient air. The system 100 includes a harvesting unit 110, and passage 111 which is shown in exploded view in Figure 1, and a refrigerant source 138 not shown in Figure 3a.

Figure 4 illustrates an embodiment of an operational flow process 200 of the system 100. Upon supplying electrical power to the system 100, as shown in a step 202, the controller 148 samples data determined or measured by the temperature measurement device 142 and/or the relative humidity measurement device 144 to obtain measured data therefrom (step 204). The sampling of data can be done at predetermined regular or irregular intervals.

The controller 148 then analyses the measured data in step 206 and selects a mode of operation in step 208. Depending on embodiment details, the mode of operation can be automatically selected by the controller 148 or in response to user inputs. In step 210, the measured data can be displayed for visual monitoring by an operator of the system 100. Following that, in step 212, the controller 148 determines a set of control parameters to operate the air energizer 116, ventilator 126, and/or actuator valve 140 according to the mode of operation that is determined in step 208. More details will be discussed later. Further, in a step 214, the controller 148 determines or looks up required control signals for required parts of the system 100 based on the measured data. In a step 216, corresponding control parameters and/or signals provided by the steps 212 and 214 are issued to the corresponding elements of the system 100. An example of operating the system 100 is provided hereinafter.

The controller 148 selects a first mode of operation denoted as a EFFICIENT mode when (a) the ambient temperature measured by the temperature measurement device 142 is greater than a first predetermined threshold TPL_{01}, (b) the ambient relative humidity measured by the relative humidity measurement device 144 is equal or greater than a predetermined level RHL, and (c) if a water storage tank is present (coupled to the system 100) and the external water storage tank does not indicate full state (not shown).

If the above conditions are met, the controller 148 activates the actuator valve 140 to allow the pressurized hot refrigerant from the refrigerant source 138 to flow into the inlet channel 130. The pressurized hot refrigerant is conveyed to the air energizer 116 via the inlet channel 130. The air energizer 116 is also in thermal communication with the ambient air. The pressurized hot refrigerant is then flowed to the heat dissipating unit 120 to further radiate the heat built up in the hot refrigerant before flowing to the condenser 118. The partially cooled refrigerant enters the condenser 118 through a small aperture (not shown) where the pressure of the refrigerant drops and evaporates into gas. The vapourized cooled refrigerant is then circulated from the condenser 118 back to the refrigerant source 138 by means of the return channel 136. The vapourized cooled refrigerant passaging through the condenser 118 receives heat from the energized air during thermal interaction of the energized air with the condenser 118. The vapourized cooled refrigerant is then transportable to the refrigerant source 138 for re-pressurization thereby subsequent to passaging through the condenser 118.

Excessive airflow generated by the ventilator 126 may hamper the harvesting of water vapour from the ambient air. As such, the speed of the airflow and volume of air generated by the ventilator 126 can be controlled at a predetermined optimised rate. The controller 148 can control the ventilator 126 and the controller 148 attains a predetermined airflow by adjusting a fan speed of the ventilator 126. In a first mode (EFFICIENT) of operation, the controller 148 sets the fan speed of the ventilator 126 to medium or high. The ambient air is then controllably induced into the system 100 by the ventilator 126. The incoming air first passes through the air filter 124 followed by an air energizing field created by the air energizer 116. The energized air then passes through the condenser 118 and surrounds the surface of the condenser 118 in which condensation of water vapour takes place. The water droplets obtained after condensation drips onto the water collection pan 128 and are directed into the water storage tank if present.

The vibrating actuator 122 which provides a subtle quivering effect, (e.g. caused by the rotation of a rotor), is coupled to the condenser 118 and is activated periodically to help to trickle water droplets from the surfaces of the condenser 118. The controller 148 can activate the vibrating actuator 122 on either a continuous or regular basis.

During the EFFICIENT mode and if the water storage tank is present and the water storage tank indicates a FULL state, the controller 148 deactivates the actuator valve 140 and stops all the steps required to harvest atmospheric water.

The controller 148 can select a second mode of operation denoted as a LOW mode when (a) the ambient temperature measured by me temperature measurement device 142 falls between the first predetermined threshold TPL_{01} and a second predetermined threshold TPL_{02}, (b) the ambient relative humidity measured by the relative humidity measurement device 140 is equal to or greater than the predetermined level RHL, and (c) if the water storage tank is present (coupled to the system 100) and the water storage tank does not indicate FULL status (not shown).

If the above conditions are met, the controller 148 operates the system 100 through the same control and decision-making steps as performed for the EFFICIENT mode. The only exception is that the fan speed of the ventilator 126 is set to low to increase the thermal interaction between the ambient air and the air energizer 116. This helps to convect incoming air current in the vicinity of the air energizer 116 to increase internal energy of the ambient air to uplift the dew point of the ambient air, which leads to higher water vapour condensation efficiency when the ambient air temperature is low.

The controller 148 can select a third mode of operation denoted as a SUSPEND mode when (a) the ambient temperature measured by the temperature measurement device 142 falls below the second predetermined threshold TPL_{02}, or (b) the ambient relative humidity measured by the relative humidity measurement device 144 falls below a predetermined level RHL, or (c) if the water storage tank is present (coupled to the system 100) and the water storage tank indicates FULL state (not shown).

If any of the above conditions are met, the controller 148 stops all the steps required to harvest atmospheric water. However, the vibrating actuator 122, the air energizer 116 and the ventilator 124 can continue to operate controllably by the controller 148 to dry any water droplets on the surface of the condenser 118 to suppress the undesired growth of mold and algae on the surface of the condenser 118. The controller 148 can also continue to monitor and/or process one or more measurement means in some embodiments.

Representative parameters that are preferably used in the system 100 for harvesting atmospheric water are as follows:

1) TPL_{01} = 20°C and TPL_{02} = 10°C, as temperature threshold values used for classifying the modes of operation; and

2) RHL = 25%, as relative humidity threshold values used for classifying the modes of operation.

The system 100 for harvesting water vapour from the ambient air for obtaining potable water provides a solution to water harvesting without the need for extensive water distribution networks. Hence, the system 100 is well suited for indoor, outdoor, fixed and mobile applications. Further, as the system 100 is able to ride on external cooling sources such as existing refrigeration and central air system to tap required refrigerant, the system 100 offers a cost- effective water making system with relatively low equipment, operational and maintenance costs.

Furthermore, the system 100 is able to operate at an ambient air temperature of as low as 5°C, thus making the system 100 well suited for many indoor and outdoor, fixed and mobile applications not only in tropical regions, but also in temperate areas with ambient air temperatures well below what conventional systems are designed to operate at.

In the foregoing manner, an atmospheric water harvesting system, apparatus and a method for harvesting atmospheric water are described according to embodiments of this disclosure for addressing at least one of the foregoing disadvantages. Although particular embodiments are described, these embodiments are not to be limited to specific forms or arrangements of parts so described and it will be apparent to one skilled in the art in view of this disclosure that numerous changes and/or modifications can be made without departing from the scope and spirit of this disclosure.

Claims

1. A water harvesting system for obtaining potable water from ambient air, wherein the potable water includes water droplets, wherein the ambient air comprises water vapour, wherein the ambient air is characterized by a temperature and a relative humidity level, the system comprising:
an ambient air intake means adapted to receive a supply of ambient air and adapted to convey received ambient air along an air travel path;
an air energizing means disposed along the air travel path, the air energizing means adapted to increase the temperature of the received ambient air to produce energized ambient air, wherein the energized ambient air comprises water vapour; and
a condenser means disposed along the air travel path, the condenser means having at least one surface adapted to extract water from the energized ambient air that is exposed to the at least one surface of the condenser means,
wherein the at least one surface of the condenser means has a temperature that is lower than that of the energized ambient air.

2. The system of claim 1, wherein the energized ambient air has a temperature that exceeds the temperature of the received ambient air by approximately 3 to approximately 15 degrees Celsius.

3. The system of claim 2, wherein the energized ambient air has a temperature that exceeds the temperature of the received ambient air by approximately 5 to approximately 10 degrees Celsius.

4. The system of claim 1, wherein the condenser means comprises coiled type elements having a plurality of coils.

5. The system of claim 4, wherein the plurality of coils are formed from cylindrical tubes of approximately 0.5 to 0.8 mm in diameter.

6. The system of claim 5, wherein the plurality of coils are formed from cylindrical tubes of approximately 0.7 mm in diameter.

7. The system of claim 1, wherein the air energizing means comprises a first surface area and the condenser means comprises a second surface area.

8. The system of claim 7, wherein the ratio of the first surface area to the second surface area is 0.6 : 1.

9. The system of claim 1, further comprising a housing adapted to house the ambient air intake means, the air energizing means and the condenser means.

10. The system of claim 1, further comprising a reservoir adapted to receive the extracted water.

11. The system of claim 1, further comprising a refrigerant source adapted to supply refrigerant to at least one of the air energizing means and the condenser means.

12. The system of claim 11, further comprising:
a first channeling passage for supplying the refrigerant to the air energizing means, wherein the refrigerant is in thermal communication with the air energizing means;
a heat dissipating unit;
a second channeling passage for supplying the refrigerant to the heat dissipating unit adapted to cool the refrigerant; and
a third channeling passage for supplying the cooled refrigerant to the condenser means for cooling the condenser means.

13. The system of claim 9, further comprising a ventilator adapted to perform at least one of,
displacing the ambient air into the housing; and

directing the ambient air into the housing.

14. The system of claim 13, wherein the ventilator is further adapted to regulate a volume of ambient air across the condenser means.

15. The system of claim 12, further comprising an actuator valve adapted to control the supply of the refrigerant into the first channeling passage.

16. The system of claim 1, further comprising an air filtering means adapted to filter the ambient air.

17. The system of claim 1, further comprising a controller adapted to control the system.

18. The system of claim 17, wherein the controller includes a microcontroller.

19. The system of claim 17, wherein control of the system is by way of selecting a mode from a plurality of modes.

20. The system of claim 19, wherein the plurality of modes include an efficient mode, a low mode and a suspend mode, wherein the efficient mode is selected when the ambient air temperature is greater than a first predetermined temperature threshold and the ambient relative humidity is equal or greater than a first predetermined humidity threshold, wherein the low mode is selected when the ambient air temperature falls between the first predetermined temperature threshold and a second predetermined temperature threshold and the ambient relative humidity is equal or greater than the first predetermined humidity threshold, wherein the suspend mode is selected when the ambient air temperature falls below the second predetermined temperature threshold and the ambient relative humidity is below the first predetermined humidity threshold.

21. The system of claim 1, further comprising a vibrating actuator is disposed in the vicinity of the condenser means.

22. The system of claim 21, wherein the vibrating actuator provides quivering effects to expedite a water trickling speed on the at least one surface of the condenser means, thereby allowing the at least one surface of the condenser means to be re-conditioned for condensing water vapour in the energized ambient air into water droplets.

23. The system of claim 1 further comprising at least one of,
a temperature measuring device adapted to measure the ambient air temperature; and
a humidity measurement device adapted to measure the ambient air relative humidity levels.

24. A water harvesting apparatus comprising:
an ambient air intake device;
an air energizer; and
a condenser,
wherein the air energizer is disposed in the periphery of the ambient air intake device.

25. The water harvesting apparatus of claim 24, further comprising a housing, wherein the housing carries at least one of,
the ambient air intake device;
the air energizer; and
the condenser.

26. The water harvesting apparatus of claim 24, further comprising a reservoir disposed in the vicinity of the condenser.

27. The water harvesting apparatus of claim 24, further comprising a refrigerant source coupled to at least one of,
an actuator valve; and
the condenser.

28. The water harvesting apparatus of claim 24, further comprising a heat dissipating unit coupled to at least one of,
the air energizer; and
the condenser.

29. The water harvesting apparatus of claim 28, further comprising a ventilator disposed in the vicinity of the heat dissipating unit.

30. The water harvesting apparatus of claim 29, further comprising an exhaust disposed in the vicinity of the ventilator.

31. The water harvesting apparatus of claim 24, further comprising at least one of,
a temperature measuring device; and
a humidity measuring device.

32. A method of harvesting potable water from ambient air; wherein the ambient air is characterized by a temperature and a relative humidity level, the method comprising:
exposing the ambient air to an air energizing means;
increasing the temperature of the ambient air by way of the air energizing means;
channeling the ambient air for thermal interaction with a condenser means; and
extracting water from the ambient air.

33. The method of claim 32 further comprising at least one of,
channeling the ambient air into a housing;
filtering the ambient air;

regulating the intake of the ambient air;
supplying a refrigerant;
regulating the supply of the refrigerant;
channeling the said refrigerant to the air energizing means;
heating the said refrigerant;
channeling the said heated refrigerant to a heat dissipating unit;
cooling the heated refrigerant; and
channeling the cooled refrigerant to the condenser means.

34. The method of claim 32, wherein the temperature of the ambient air is increased by approximately 3 to approximately 15 degree Celsius.

35. The method of claim 32 further comprising at least one of,
determining the temperature of the ambient air; and
determining the relative humidity level of the ambient air.

36. The method of claim 35 comprising at least one of,
analyzing the said temperature of the ambient air; and
analyzing the said relative humidity of the ambient air.

37. The method of claim 32 performed by the water harvesting system of claim 1.

38. The method of claim 32 further comprising selecting a mode of operation of the water harvesting system from a plurality of modes of operation, wherein the mode of operation is selected based upon at least one of,
the ambient temperature of the ambient air; and
the relative humidity level of the ambient air.

39. The method of claim 38, wherein the plurality of modes of operation includes an efficient mode, a low mode and a suspend mode, wherein the efficient mode is selected when the ambient air temperature is greater than a first predetermined

temperature threshold and the ambient relative humidity is equal or greater than a first predetermined humidity threshold, wherein the low mode is selected when the ambient air temperature falls between the first predetermined temperature threshold and a second predetermined temperature threshold and the ambient relative humidity is equal or greater than the first predetermined humidity threshold, wherein the suspend mode is selected when the ambient air temperature falls below the second predetermined temperature threshold and the ambient relative humidity is below the first predetermined humidity threshold.

40. The method of claim 32, wherein at least a portion of the method is controlled by computer software.

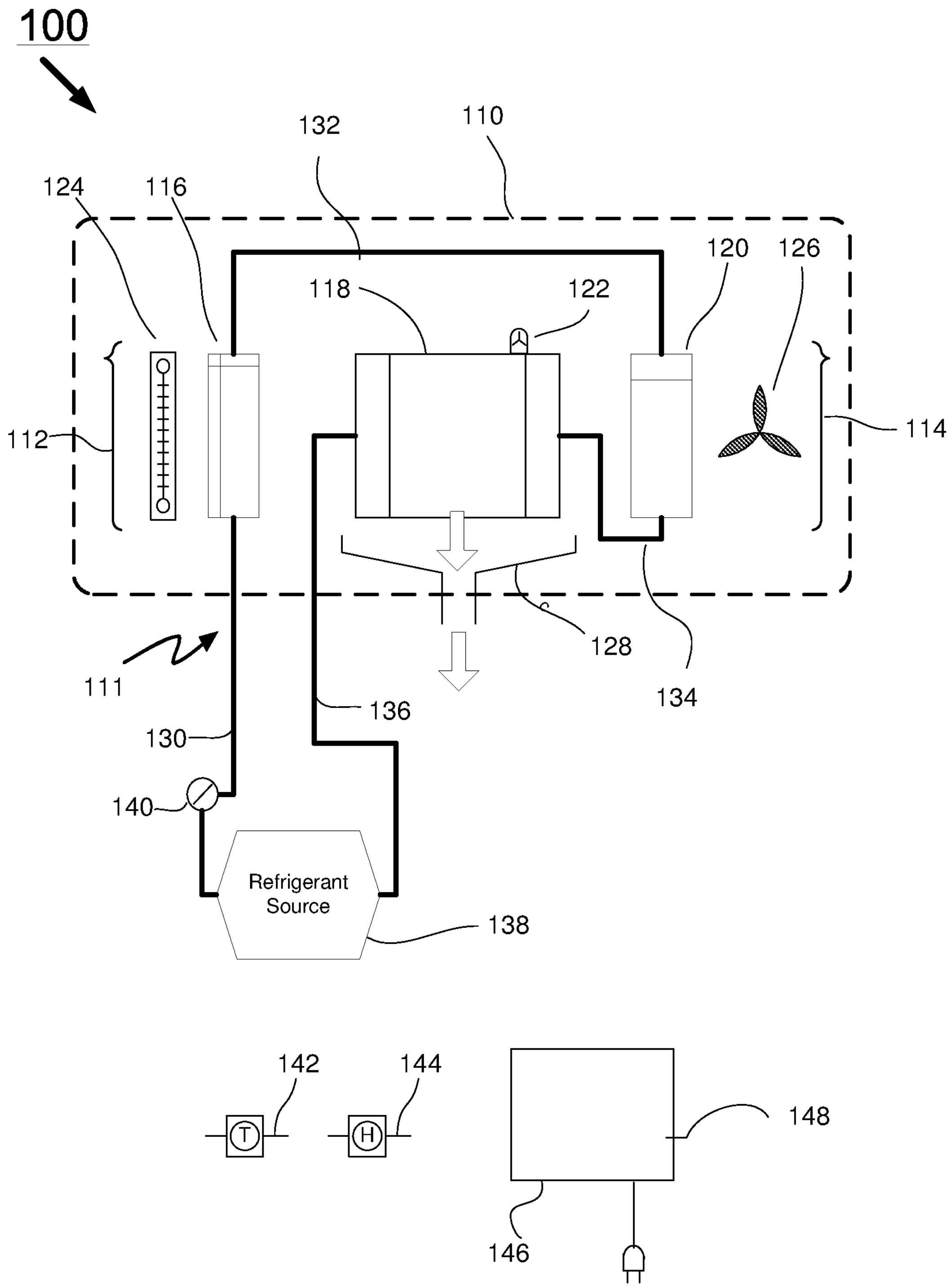
100
132
110
124
116
120
126
118
122
112
114
128
134
111
136
130
140
Refrigerant
Source
138
142
144
148
146

Figure 1

Ambient Air Temperature °C	Ambient Air R. Humidity %	Air Energizer Height In Ratio to Condenser	Air Energizer Distance to Condenser (mm)	Condenser Tube Size (mm)	Condenser Size Size In Ratio to HDU	Condenser No. of Surfaces Per Inch Size	Heat Dissipating Unit Tube Size (mm)	Air Flow (CFM)	Water Production Rate (Litres per hour)	Water Production Rate (Litres per day)	Performance
20	60	NIL	20	9.375	1 : 1	12	0.9375	500	0.5556	13.3344	—
20	60	NIL	20	9.375	0.75 : 1	12	0.9375	500	0.61116	14.66784	110.00%
20	60	NIL	20	9.375	0.5 : 1	12	0.9375	500	0.52782	12.66768	95.00%
20	60	NIL	20	9.375	0.25 : 1	12	0.9375	500	0.38892	9.33408	70.00%
20	60	1 : 1	20	7	1 : 1	12	7	500	0.7828	18.7872	140.89%
20	60	1 : 1	20	7	0.75 : 1	12	7	500	0.884564	21.22954	159.21%
20	60	1 : 1	20	7	0.5 : 1	12	7	500	0.74366	17.84784	133.85%
20	60	1 : 1	20	7	0.25 : 1	12	7	500	0.54796	13.15104	98.62%
20	60	0.75 : 1	20	7	1 : 1	12	7	500	0.80237	19.25688	144.42%
20	60	0.75 : 1	20	7	0.75 : 1	12	7	500	0.906678	21.76027	163.19%
20	60	0.75 : 1	20	7	0.5 : 1	12	7	500	0.762251	18.29404	137.19%
20	60	0.75 : 1	20	7	0.25 : 1	12	7	500	0.561659	13.47982	101.09%
20	60	0.5 : 1	20	7	1 : 1	12	7	500	0.74366	17.84784	133.85%
20	60	0.5 : 1	20	7	0.75 : 1	12	7	500	0.840336	20.16806	151.25%
20	60	0.5 : 1	20	7	0.5 : 1	12	7	500	0.706477	16.95545	127.16%
20	60	0.5 : 1	20	7	0.25 : 1	12	7	500	0.520562	12.49349	93.69%
20	60	0.75 : 1	30	7	1 : 1	12	7	500	0.778299	18.67917	140.08%
20	60	0.75 : 1	30	7	0.75 : 1	12	7	500	0.879478	21.10747	158.29%
20	60	0.75 : 1	30	7	0.5 : 1	12	7	500	0.739384	17.74521	133.08%
20	60	0.75 : 1	30	7	0.25 : 1	12	7	500	0.544808	13.07542	98.06%
20	60	0.75 : 1	10	7	1 : 1	12	7	500	0.778299	18.67917	140.08%
20	60	0.75 : 1	10	7	0.75 : 1	12	7	500	0.879478	21.10747	158.29%
20	60	0.75 : 1	10	7	0.5 : 1	12	7	500	0.739384	17.74521	133.08%
20	60	0.75 : 1	10	7	0.25 : 1	12	7	500	0.544809	13.07542	98.06%

Figure 2

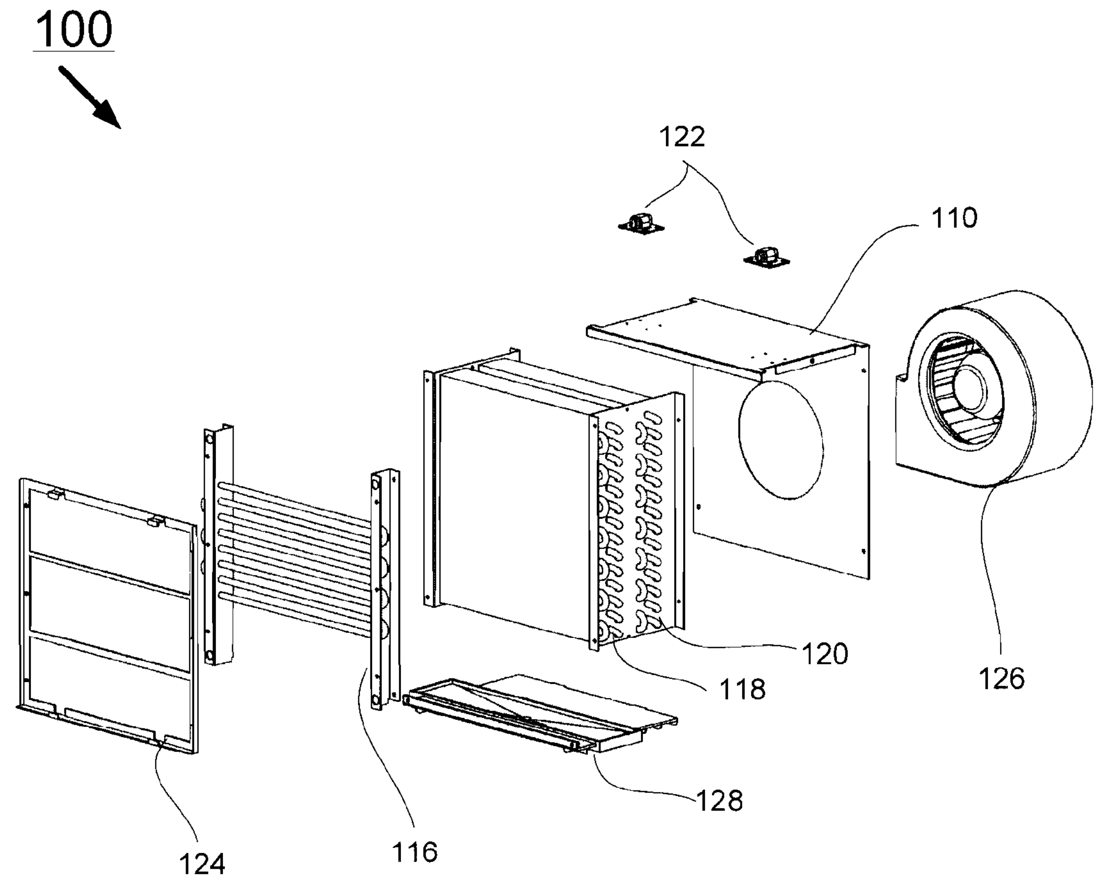

Figure 3a

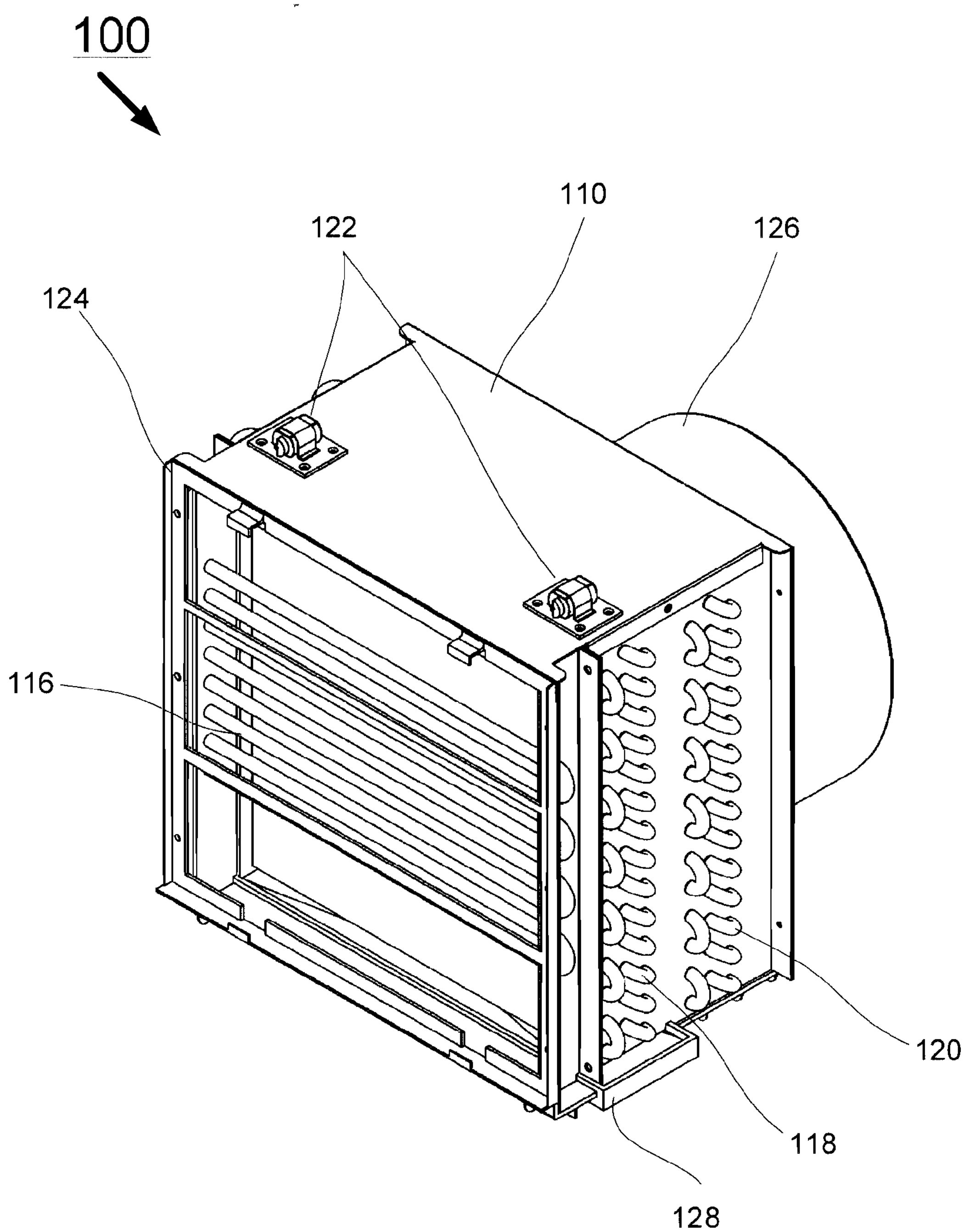

Figure 3b

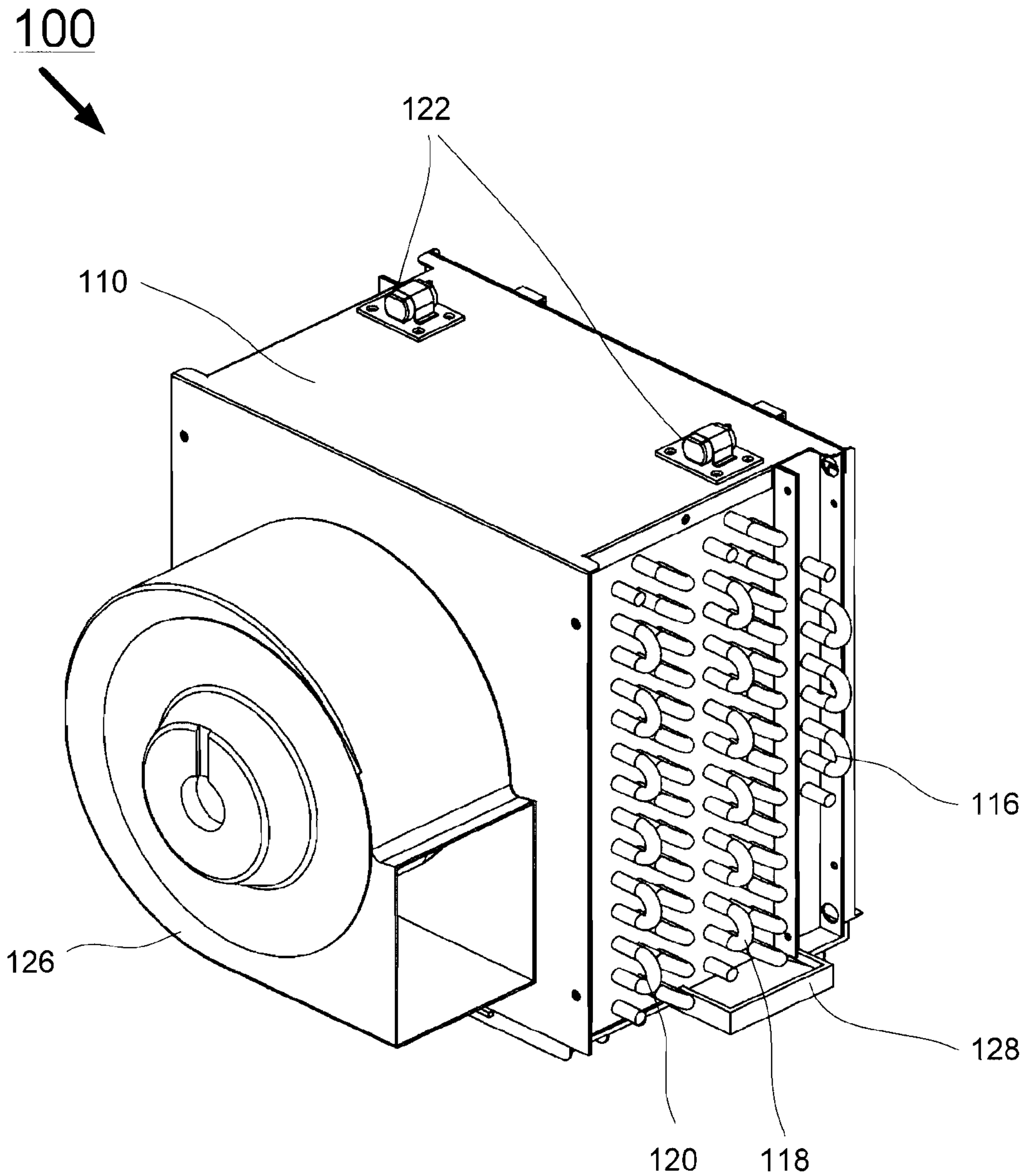

Figure 3c

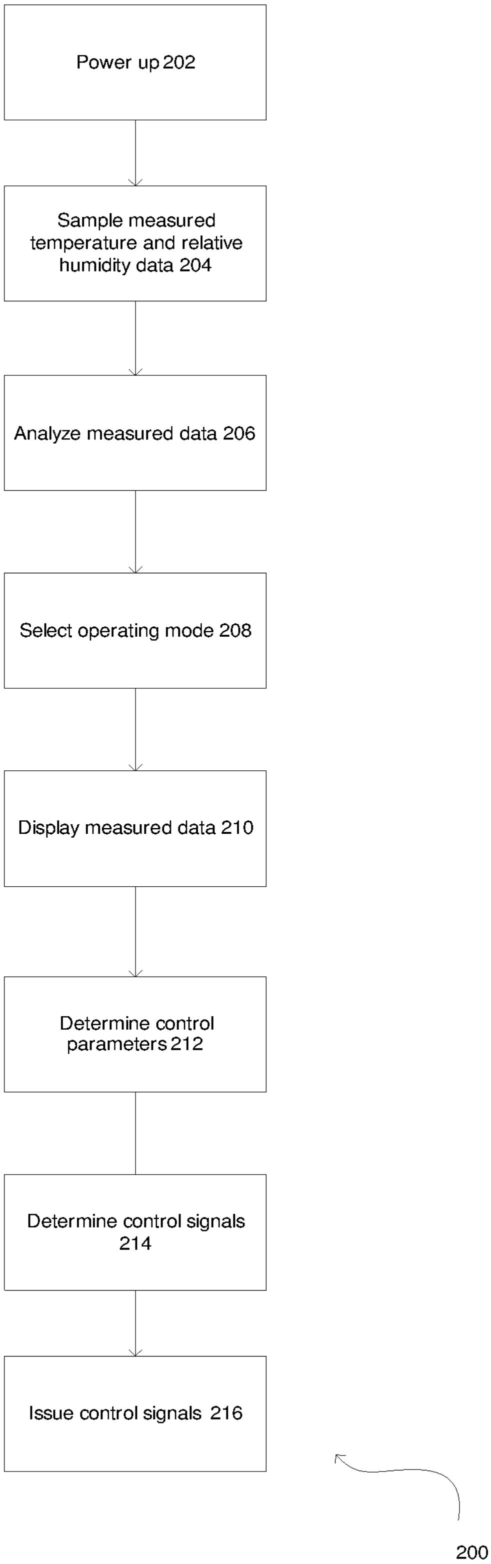
Power up 202
Sample measured temperature and relative humidity data 204
Analyze measured data 206
Select operating mode 208
Display measured data 210
Determine control parameters 212
Determine control signals 214
Issue control signals 216
200

Figure 4