

VARIABLE CAPACITY EVAPORATIVE COOLING SYSTEM FOR AIR AND WATER CONDITIONING

FIELD OF THE INVENTION

[0001] The invention relates to an evaporative cooling system, and more specifically, to a multi-component evaporative cooling system with variable capacity and temperature control for conditioning air and water.

BACKGROUND

[0002] Conventional air cooling systems or air conditioners (AC's) utilize a complicated array of pipes with a condenser and compressor. A circulating refrigerant such as a chlorofluorocarbon (CFC) is forced into a compressor. Its subsequent release extracts heat from the surrounding air as it expands. These cooling systems consume high levels of energy and can be expensive to own and operate. Efforts have focused on alternative systems that are more environmentally friendly and cost effective.

[0003] The temperature of dry air can be lowered by utilizing the phase transition of liquid water to water vapor (i.e. evaporation). Evaporative cooling can be described as the addition of water vapor into air which lowers the temperature of the air. The energy needed to evaporate the water is taken from the air in the form of sensible heat and converted into latent heat while the enthalpy of the air remains constant. This conversion of sensible heat to latent heat is known as an adiabatic process because it occurs at a constant enthalpy. Evaporative cooling therefore causes a drop in the temperature of air proportional to the sensible heat drop and an increase in humidity proportional to the latent heat gain.

[0004] Basic evaporative cooling systems use a fan and an evaporative medium. A low pressure, high volume air mover is mounted in a housing that incorporates a large area of porous evaporation pads. Ambient air is circulated through the system where it

is cooled and humidified. Because of their simple design, evaporative cooling systems can be more economical than vapor compression systems. However, the air conditioning ability of evaporative cooling systems is limited by the temperature and humidity of the ambient air.

[0005] The cooling potential for evaporative cooling is dependent on the wet-bulb depression, the difference between dry-bulb temperature and wet-bulb temperature. Alternatives such as multi-stage evaporative coolers or dew point coolers can be used in attempt to overcome this limitation. For example, U.S. Patent Publication Number 2009/0031748 describes an evaporative cooling system that cools air to a temperature below that of the wet bulb temperature. It includes a reservoir of water that is chilled. The cooler water is purported to evaporate more slowly and assist in the overall efficiency of the system. A rotating disc sprays chilled water droplets upward to expose air to a fog-like curtain prior to exiting the chamber.

[0006] Similarly, Patent Application Number WO/2017/138889 describes a system for cooling an outdoor space comprising a main cooling module, a heat rejection module, a water management module and a control module. The main cooling module includes an indirect evaporative cooling unit for pre-cooling ambient air by reducing sensible heat and a direct evaporative cooling unit having a first evaporative medium for cooling the pre-cooled air (or direct ambient air) through vaporization of water to generate a conditioned supply air with a lower wet bulb temperature than the ambient air. A heat rejection module includes a second evaporative medium for removing heat contained in the water recycled from the indirect evaporative cooling unit thereby producing cool water having a temperature almost equivalent to the intake ambient air wet bulb temperature.

[0007] Patent Application Number WO/2017/078616 describes the configuration, control and operation of a multi-component air-conditioning system. The system includes an environmental sensor, a controlling chip and a plurality of cooling components. The cooling components are activated or inactivated according to a most

efficient operating mode. The operating mode is determined based on environmental parameters sensed by a sensor to deliver an effective and efficient temperature reduction.

[0008] Patent Application Number WO/2018/021967A1 describes an apparatus with a fluid storage device for holding a volume of coolant, a cooling device with a heat exchanger and a first evaporative media arranged in fluid communication with the fluid storage device. A heat rejection device includes a second evaporative media arranged in fluid communication with the fluid storage device and the heat exchanger. The apparatus can be operated in two modes. In the first mode, the first evaporative media is activated to use the coolant to cool the air to a first temperature. In the second mode, the first and second evaporative media and the heat exchanger are collectively activated to cool the air to a temperature lower than the first temperature.

[0009] While these inventions present alternatives to conventional air conditioning systems, there is a need for an improved design. These systems are designed to maximize temperature reduction regardless of conditions. While the air flow rate can be controlled, the output temperature control cannot be adjusted. The control and operation of an improved evaporative cooling system should allow for variable capacity and temperature control for conditioning air and water.

SUMMARY OF THE INVENTION

[0010] The following summary is provided to facilitate an understanding of some of the innovative features unique to the disclosed embodiment and is not intended to be a full description. A full appreciation of the various aspects of the embodiments disclosed herein can be gained by taking into consideration the entire specification, claims, drawings, and abstract as a whole.

[0011] Embodiments include a system for cooling air or water. The system can include (a) a cooling unit, (b) a heat rejection unit, (c) a water management system and

(d) a chamber separation plate. The cooling unit can include a sensible heat exchanger and an evaporative porous media unit. The chamber separation plate separates the cooling unit and the heat rejection unit and can move along a shaft such that its position determines the capacities of the cooling unit and the heat rejection unit.

[0012] A control system can maintain a target air or water temperature by controlling fan speed, water circulation and/or the position of the chamber separation plate. The water management system can control the flow of water through the sensible heat exchanger and/or the evaporative porous media unit. The cooling unit can include multiple sensible heat exchangers and/or multiple evaporative porous media units. The heat rejection unit can exhaust warm air from the system and cool water adiabatically, using evaporative porous media. One or more sensors can monitor ambient temperature and/or humidity levels.

[0013] Embodiments also include a method of conditioning air or water comprising steps of (a) directing ambient air into a cooling unit, (b) circulating water through the cooling unit, (c) conditioning the ambient air using a heat exchanger to obtain sensible cooled air and/or adiabatically treating the sensible cooled air with evaporative porous media, (d) exhausting warm air with a heat rejection unit, (e) collecting sensor data from one or more sensors, (f) analyzing the sensor data and user preferences to determine capacities of the cooling unit and heat rejection unit and (g) adjusting the position of a chamber separation plate to control the capacities of the cooling unit and the heat rejection unit. The method can use a control system to maintain a target temperature by controlling fan speed, water circulation and/or the shaft position of the chamber separation plate. The method can use a water management system to control the flow of water through the sensible heat exchanger and/or the evaporative porous media. Air can be further conditioned in a second sensible heat exchanger and/or a second evaporative porous media unit contained within the cooling unit.

Introduction

[0014] A first aspect of the invention is a variable capacity evaporative cooling

system that conditions both air and water.

[0015] A second aspect of the invention is a cooling system that cools ambient air by sensible heat reduction and adiabatic cooling.

[0016] A third aspect of the invention is a cooling system that includes four separate units: a cooling unit, a heat rejection unit, a water management system and a control system.

[0017] A fourth aspect of the invention is a cooling system that uses one or more heat exchangers operating in series or parallel.

[0018] A fifth aspect of the invention is a cooling system that uses one or more evaporative media units operating in series or parallel.

[0019] A sixth aspect of the invention is a cooling system with a chamber separation plate that separates the cooling unit and the heat rejection unit that can be adjusted along a shaft to vary the output of each unit.

[0020] A seventh aspect of the invention is an evaporative cooling system that operates in different modes by altering the circulation of air and/or water.

[0021] An eighth aspect of the invention is a smart algorithm that analyzes ambient conditions to select the most energy efficient cooling mode to achieve a desired temperature.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The summary above, as well as the following detailed description of illustrative embodiments, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the present disclosure, exemplary

constructions of the disclosure are shown in the drawings. However, the disclosure is not limited to specific methods and instrumentalities disclosed herein. Moreover, those in the art will understand that the drawings are not to scale. Wherever possible, like elements have been indicated by identical numbers.

[0023] FIG. 1 depicts a cross-sectional view of the components of a variable capacity evaporative cooling system and the flow of air through the system.

[0024] FIG 2A depicts the components of a variable capacity evaporative cooling system in a square base form.

[0025] FIG 2B depicts a partial internal view of the components of a variable capacity evaporative cooling system in a square base form.

[0026] FIG. 3A depicts a cross-sectional view of a variable capacity evaporative cooling system with the chamber separation plate in a first position.

[0027] FIG. 3B depicts a cross-sectional view of a variable capacity evaporative cooling system with the chamber separation plate in a second position.

[0028] FIG. 3C depicts a cross-sectional view of a variable capacity evaporative cooling system with the chamber separation plate in a third position.

[0029] FIG. 3D depicts a cross-sectional view of a variable capacity evaporative cooling system with the chamber separation plate in a fourth position.

[0030] FIG. 4A is a schematic diagram of water circuits in a variable capacity evaporative cooling system.

[0031] FIG. 4B is a schematic diagram of water circuits in a variable capacity evaporative cooling system with two evaporative media units.

[0032] FIG. 4C is a schematic diagram of water circuits in a variable capacity evaporative cooling system with two evaporative media units and two air-water heat exchange units.

[0033] FIG. 5 is a flowchart that depicts the use of an algorithm to adjust output of the variable capacity evaporative cooling system.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

[0034] The particular values and configurations discussed in these non-limiting examples can be varied and are cited merely to illustrate at least one embodiment and are not intended to limit the scope thereof. While the invention is described for the conditioning air that is expelled into a room or gathering place, it is understood that the invention is not so limited and can be used to assist with other types of applications that require conditioned air. Other applications include, for example, using the system to condition air for controlled environments. It can be used instead of conventional refrigerants to chill food or other perishable materials. It can condition air and/or remove heat from industrial settings and/or areas with electronic circuits that generate heat. The invention can also be scaled down and up for an intended use. Further, it can be used to condition fluid/water for consumption and/or applications that use chilled fluid/water.

[0035] Reference in this specification to "one embodiment/aspect" or "an embodiment/aspect" means that a particular feature, structure, or characteristic described in connection with the embodiment/aspect is included in at least one embodiment/aspect of the disclosure. The use of the phrase "in one embodiment/aspect" or "in another embodiment/aspect" in various places in the specification are not necessarily all referring to the same embodiment/aspect, nor are separate or alternative embodiments/aspects mutually exclusive of other embodiments/aspects. Moreover, various features are described which may be

exhibited by some embodiments/aspects and not by others. Similarly, various requirements are described which may be requirements for some embodiments/aspects but not other embodiments/aspects. Embodiment and aspect can be in certain instances be used interchangeably.

[0036] The terms used in this specification generally have their ordinary meanings in the art, within the context of the disclosure, and in the specific context where each term is used. Certain terms that are used to describe the disclosure are discussed below, or elsewhere in the specification, to provide additional guidance to the practitioner regarding the description of the disclosure. For convenience, certain terms may be highlighted, for example using italics and/or quotation marks. The use of highlighting has no influence on the scope and meaning of a term; the scope and meaning of a term is the same, in the same context, whether or not it is highlighted. It will be appreciated that the same thing can be said in more than one way.

[0037] Consequently, alternative language and synonyms may be used for any one or more of the terms discussed herein. Nor is any special significance to be placed upon whether or not a term is elaborated or discussed herein. Synonyms for certain terms are provided. A recital of one or more synonyms does not exclude the use of other synonyms. The use of examples anywhere in this specification including examples of any terms discussed herein is illustrative only, and is not intended to further limit the scope and meaning of the disclosure or of any exemplified term. Likewise, the disclosure is not limited to various embodiments given in this specification.

[0038] Without intent to further limit the scope of the disclosure, examples of instruments, apparatus, methods and their related results according to the embodiments of the present disclosure are given below. Note that titles or subtitles may be used in the examples for convenience of a reader, which in no way should limit the scope of the disclosure. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure pertains. In the case of conflict, the present document, including

definitions, will control.

[0039] The term “adiabatic” refers to a process that occurs without transfer of heat or matter between a thermodynamic system and its surroundings. In an adiabatic process, energy is transferred to its surroundings only as work (e.g. vaporization of water).

[0040] The term “ambient” refers to a condition of outside air at the location at or near the cooling system.

[0041] The term “dew point temperature” refers to the temperature at which air must be cooled to become saturated with water. Air normally contains a certain amount of water vapor. The maximum amount of water vapor that air can hold depends upon the temperature of the air, sometimes referred to as dry bulb temperature (T_{db}).

[0042] The term “damper” refers to any device or component that can be moved to control (e.g. increase or decrease) the flow of air or liquid through a duct or passage way. Examples of dampers include plates, blades, panels, or discs, or any combination thereof. A damper can include multiple elements. For example, a damper can include a series of plates in parallel relation to one another that can be simultaneously rotated to close a duct.

[0043] The “dry-bulb temperature” refers to the temperature indicated by a thermometer exposed to the air in a place sheltered from radiation and moisture. The term “dry-bulb” is customarily added to temperature to distinguish it from wet-bulb and dew point temperature.

[0044] The term “evaporative cooler” or “swamp cooler” refers to a device that cools air through the evaporation of water. The temperature of dry air can be lowered through the phase transition of liquid water to water vapor (evaporation). This can cool air without energy that is necessary for other refrigeration techniques.

[0045] The term “evaporative porous media” refers to a material that permits the relatively unobstructed evaporation of water into air. For example, a sheet of cotton fabric can be used to allow water to evaporate into ambient air. Evaporation behavior in layered porous media is affected by thickness and sequence of layering and capillary characteristics of each layer.

[0046] The term “heat exchanger” refers to a device used to transfer heat between two or more fluids and/or gases. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. As used herein, temperature change is achieved sensibly with a heat exchanger.

[0047] The term “sensible” refers to heat exchanged by a body or thermodynamic system in which the exchange of heat changes the temperature of the body or system, and some macroscopic variables of the body or system, but leaves unchanged certain other macroscopic variables of the body or system, such as volume or pressure.

[0048] The “wet-bulb depression” refers to the difference between the dry-bulb temperature and the wet-bulb temperature.

[0049] The term “wet bulb temperature” refers to the temperature read by a thermometer covered in water-soaked cloth over which air is passed. At 100% relative humidity, the wet-bulb temperature is equal to the air temperature and is lower at lower humidity. It can be defined as the temperature of a parcel of air cooled to saturation (100% relative humidity) by the evaporation of water into it, with the latent heat supplied by the parcel. The wet-bulb temperature is the lowest temperature that can be reached under current ambient conditions by the evaporation of water only.

[0050] The term “wicking” refers to the spontaneous transport of a liquid through a porous medium as a result of capillary suction taking place at liquid-gas interfaces at the surface or within the porous medium.

Numerical Reference Features

The following numerical index is provided for ease in cross-referencing between the structural features illustrated in the figures and the accompanying description provided herein.

100	–	Variable Capacity Cooling System
110	–	Heat Rejection Unit
120	–	Cooling Unit
130	–	Exhaust Fan
140	–	Evaporative Porous Media
150	–	Chamber Separation Plate
160	–	Air Water Heat Exchanger
170	–	Supply Fan
180	–	Water Reservoir
190	–	Water Control Valve
210	–	Water Pump
220	–	Vertical Shaft

Description of Preferred Embodiments

[0051] Embodiments include a variable capacity evaporative cooling system for water and air conditioning. The system can be packaged as a stand-alone unit with an air intake to draw in ambient air and an air return duct to expel conditioned air. The system can also include components that are common in the art to monitor and control air flow and temperatures such as circuits, fans, valves, pipes, filters and a user interface.

[0052] The system can use two air conditioning mechanisms. The first is a heat exchanger that uses sensible heat reduction. The second uses evaporative porous media for an adiabatic cooling process whereby sensible heat is converted to latent

heat through the vaporization of water. The combination of these conditioning mechanisms allow for outlet supply temperatures lower than the pre-treatment wet bulb temperature.

[0053] The system includes four distinct units: a cooling unit, a heat rejection unit, a water management system and a control system. The cooling unit can condition intake air sensibly and adiabatically as well as produce cold water. The heat rejection unit can remove heat from the water circuit and produce cold water. The water management system provides circulating water for the two air conditioning mechanisms and includes pipes/tubing, pumps and valves. The control system can include a processor with the logic operation for the system and a series of input conditions and output requirements.

[0054] FIG. 1 depicts some of the components of a variable capacity evaporative cooling system **100** according to an embodiment. The system can include a cooling unit **120**, a heat rejection unit **110**, a water management system (not shown) and a control system (not shown). The air-water heat exchanger **160**, evaporative porous media **140**, supply fan **170**, exhaust fan **130**, chamber separation plate **150** and vertical shaft **220** are also depicted. The arrows show the directions of the airflow into, through and out of the system.

[0055] The supply fan **170** and the exhaust fan **130** drive ambient air into the system. Intake airflow or ambient air is depicted with dotted arrows. This air flows into the cooling unit **120** and heat rejection unit **110** where it is treated. The chamber separation plate **150** divides the two units. Air that enters the cooling unit passes through the air-water heat exchange **160** and through the evaporative porous media **140**. It is then directed out of the system as conditioned air (striped arrows). Air that enters the heat rejection unit passes through the evaporative porous media **140**. It is then directed out of the system as exhaust air flow (hatched arrow).

[0056] The conditioned air can be directed toward one or more users whereas the exhaust airflow is directed in a different direction. In one embodiment, conditioned air is

directed into a room or area inside a structure. The exhaust airflow is directed toward the outside environment. The system can also treat air in an outdoor environment, in which case, conditioned air is directed toward a one or more individuals in a gathering area.

[0057] FIG 2A depicts an exterior view of the components of a variable capacity evaporative cooling system. The exhaust fan **130** drives air out of the heat rejection unit. The evaporative porous media **140**, air-water heat exchanger **160**, water reservoir **180**, and supply fan **170** are visible from the exterior view. FIG 2B depicts a partial interior view of the components. The chamber separation plate **150** is adjustable along a vertical shaft **220**. The level of the chamber separation plate **150** determines the proportion of air that flows through each of the cooling unit **120** and the heat rejection unit **110**.

[0058] The system can be comprised of individual units that are square-shaped. FIG. 1, FIG. 2A and FIG. 2B depict one embodiment of the system wherein the components are arranged in a square base form. The cooling unit **120** forms the base with the heat rejection unit **110** on top. However, the system can function with alternative arrangements of the components. For example, a pentagonal base can include five sides, each with an air-water heat exchanger and evaporative porous media unit. Alternative arrangements are possible, such as hexagonal or octagonal base forms, with six and eight sides respectively. Further, the heat rejection unit can be positioned below the cooling unit (not shown).

Cooling Unit

[0059] As depicted in FIG. 1, the cooling unit **120** includes an air-water heat exchanger **160** and an evaporative porous media unit **140** to condition air. A supply fan **170** forces ambient air (i.e. intake air) into the system and circulates the air through the system. After ambient air enters the cooling unit **120**, it is cooled sensibly as it passes through the heat exchanger **160**. Sensible air conditioning occurs as heat is transferred

between water or another fluid and the ambient air. The heat exchanger can include a series of pipes or tubes to increase its surface area with the air. Ambient air contacts the surface of the heat exchanger which has a lower temperature than ambient air. The temperature difference between the warm ambient air and the heat exchanger results in the transfer of heat. Consequently, ambient air that enters the evaporative cooling unit is cooled sensibly to a lower temperature without increasing its absolute humidity.

[0060] The air then flows through the evaporative porous media **140**. Water flows through the evaporative porous media **140** and cools the air adiabatically through the vaporization of water. The entering air passes across the wet surface of the evaporative medium **140**. The surface water is heated and evaporates, resulting in adiabatic cooling. Thus, the temperature of the passing air is reduced through an increase in its humidity.

Heat Rejection Unit

[0061] The heat rejection unit **110** removes heat from the water circuit by cooling the circulating water. It includes an exhaust fan **130** or other apparatus to drive air out of and away from the unit. In a preferred design, the heat rejection unit is situated above the cooling unit **120**. The warm exhaust air is directed away from system, in an upward direction.

[0062] The heat rejection unit **110** expels heat from the circulating water and generates cool water to flow back to water tank **180**. Depending on the settings, water can be cooled by the heat exchanger **160** and/or the evaporative porous media **140**. The exhaust fan also pulls air through the evaporative medium **140** to facilitate the evaporative cooling process. The volume of air flow into the heat rejection unit depends on the setting of the chamber separation plate **150**.

Water Management System

[0063] The system uses circulating water for the air-water heat exchanger **160** and the evaporative porous media **140**. The water management system can include elemental units for water flow circulation and regulation, such as pumps and valves. A supply of water can be stored in a water reservoir **180**. Water from the reservoir can be pumped through the air-water heat exchanger and evaporative porous media of the cooling unit **120**.

[0064] In one embodiment, water from the reservoir **180** enters the air-water heat exchanger **160** where it cools circulating air. Thereafter, the air enters the evaporative porous media **140**. The evaporation of a portion of the water provides the adiabatic cooling to both the circulating air and water. In other embodiments, water flow is pumped from the reservoir **180** directly to the evaporative media **140**, as described below.

Chamber Separation Plate

[0065] A chamber separation plate **150** separates the cooling unit **120** and the heat rejection unit **110**. The position of the chamber separation plate **150** can be adjusted along a vertical shaft **220**. It can be manually moved and/or electronically adjusted as directed by the control system. The system can operate in different modes as the position varies the air flow capacities of the cooling unit and the heat rejection unit.

[0066] FIG. 1 depicts the flow of air through the system. The chamber separation plate **150** determines the proportion of air that flows through the heat rejection unit **110** and the cooling unit **120**. With the chamber separation plate at a high position, airflow through the heat rejection unit is reduced and airflow through the cooling unit is increased. This lowers the heat rejection capacity, increases cooling unit air flow capacity and dry-bulb temperature. Conversely, with the chamber separation plate at a low position, airflow through the heat rejection unit is increased. This increases the heat

rejection capacity, reduces cooling unit air flow capacity and dry-bulb temperature.

[0067] As mentioned, the system can function with alternative arrangements of the components. For example, the heat rejection unit can be situated below the cooling unit (not shown). With this arrangement, the operating position of the chamber separation plate **150** is reversed. With the chamber separation plate at a low position, airflow through the heat rejection unit is reduced and airflow through the cooling unit is increased. Conversely, with the chamber separation plate at a high position, airflow through the heat rejection unit is increased.

Operating Modes

[0068] The efforts of the cooling unit and heat rejection unit can be varied according to a most efficient operating mode or conditioning requirements. As described above, a chamber separation plate **150** separates the cooling unit **120** and the heat rejection unit **110**. The chamber separation plate **150** can be moved along the vertical shaft **220** to adjust the active surface area for the cooling unit and heat rejection unit. This controls the system in two ways. First, adjustment of the active surface area modulates the airflow capacities of the cooling unit and heat rejection unit. Second, it regulates the output air temperature of the cooling unit. FIG. 3A – 3D depict the system with different arrangements of the chamber separation plate **150**. In one embodiment, the system operates in one of four modes. Each mode is identified by the position of the chamber separation plate **150** at one of four positions along the vertical shaft.

Mode 1

[0069] The first mode is depicted in FIG. 3A. The plate **150** is positioned below the vertical mid-section and above the intake of the supply fan **170**. Both the cooling unit and heat rejection unit are active. As the plate **150** is located below the vertical mid-section, the cooling unit has a smaller active surface area and therefore a lower volumetric air flow capacity. This increases the heat rejection capacity, producing colder water which lowers the output (i.e. conditioned) air temperatures of the heat

exchanger **160** and evaporative porous media **140**.

Mode 2

[0070] The second mode is depicted in FIG. 3B. The plate **150** is set above the vertical mid-section and closer to the intake of the exhaust fan. Both the cooling unit and heat rejection unit are active. As the plate **150** is located above the vertical mid-section, the cooling unit has a larger active surface area than the first mode and therefore a larger volumetric air flow capacity. Air is extracted through the upper section of the evaporative porous media **140** thus increasing the output (i.e. conditioned) air temperature.

Mode 3

[0071] The third mode is depicted in FIG. 3C. The plate **150** is set at the top of the unit which seals the exhaust fan, rendering the heat rejection unit inactive. Accordingly, the exhaust fan **130** can be shut off. The cooling unit is active and operates based on the full capacity of the evaporative porous media **140**, thus maximizing the volumetric air flow capacity.

[0072] The evaporative porous media **140** remains active while the air-water heat exchanger is inactive. This mode is suitable for conditions where ambient humidity is low, allowing for a high temperature reduction potential. It provides the largest possible volumetric air flow capacity and cooling capacity. Further, under this operating mode, the cooling capacity can be further varied by adjusting the speed of the supply fan.

Mode 4

[0073] The fourth mode is depicted in FIG. 3D. The plate **150** is set at the bottom of the unit which seals the supply fan, rendering the cooling unit inactive. Accordingly, the supply fan **170** can be shut off. Only the heat rejection unit is active. Both the evaporative porous media **140** and the heat exchanger **160** are active. Alternatively, the heat exchanger can be inactivated while the evaporative porous media **140** remains active.

[0074] In this arrangement, the functional purpose of the system is to reject heat from an external source. The system can be used for the purpose of conditioning water or as a component of a water cooling system. The external source of heat can be transferred through a fluid connection that is direct, where there is a mass transfer, or indirect, where there is only a heat transfer.

Water Flow

[0075] A water system provides flowing water to the air-water heat exchanger and evaporative porous media. The water system can include a series of tubing or pipes attached in fluid communication with a reservoir tank. One or more pumps direct the flow of water through the system. Valves can adjust the pressure and flow through the tubing and pipes.

[0076] FIG. 4A is a water flow schematic for a system with a single heat exchanger and a single evaporative media unit. The circuit design is based on the physical arrangement of the system and components of FIG. 1. The water tank or reservoir **180** is in fluid communication with the heat exchanger **160** and the evaporative media **140**. A water pump **210** in conjunction with a control valve **190** can adjust the flow of water from the reservoir to the two components.

[0077] Water circulates to the air-water heat exchanger **160** and evaporative porous media **140** as depicted by the arrows. In typical operation, water flows from the water reservoir **180** through the heat exchanger **160** and the evaporative media **140**. Heated water exits the air-water heat exchanger **160** to enter the evaporative porous media **140**. As the water passes through the evaporative media **140**, heat is removed from the water, lowering its temperature to the wet bulb temperature of the air exiting the heat exchanger.

[0078] The flow of water can be configured by the control valve **190** to bypass the

air-water heat exchanger **160**. Water from the reservoir **180** can flow directly to the evaporative porous media **140** to provide evaporative cooling of air. This can be desirable, for example, when operating in the third mode as described above.

[0079] FIG. 4B depicts a system with an alternative design that includes two evaporative media units **140**. Multiple units can increase the water flow capacity and adiabatic cooling capacity. The water circuit connects the heat exchanger and both evaporative media units **140**, situated in series with one another. As described above, water circulates through the system as depicted by the arrows.

[0080] The flow of water can be configured through different paths by the control valve **190**. Water from the reservoir can be directed to flow to the heat exchanger **160** and then to the evaporative media **140**. Alternatively, water can be directed to the evaporative media **140** while bypassing the heat exchanger **160**. Further, the flow of water from the reservoir **180** can be directed to one or both of the evaporative media units **140**. Variations of the depth or width of the media are possible and can be integrated in a similar manner as depicted in FIG. 4C.

[0081] FIG. 4C depicts a system with an alternative design that includes two heat exchanger units **160** and two evaporative media units **140**. Multiple units can increase the capacity of water flow and sensible cooling capacity of both air and water. Separate air-water heat exchanger units **160** can increase the cooling capacity that is in line with the variable heights of the chamber separation plate. Here, the heat exchanger **160** includes two vertical units with water feeding into both units. Each heat exchanger **160** can be in fluid connection with a corresponding evaporative media unit **140** of similar capacity.

[0082] As in the previous examples, the flow of water can be configured through different paths by the control valves **190**. Variations of the depth or width of the heat exchanger are possible and can be integrated in a similar manner. Further, the intensity of the fan and level of the chamber separation plate can vary the heating capacity and

output temperature. In an alternative design, multiple heat exchanger units and/or multiple evaporative media units are placed in parallel to each other, rather than in series with one another (not shown).

Control System

[0083] A control system contains the logic operation of the system and a series of input conditions and output requirements. The control system can include a control algorithm and input/output devices to operate the evaporative cooling system. The control system can operate the cooling system and target a comfortable apparent temperature level by using the most energy efficient operation mode. Additionally, the control algorithm can determine a preferred operational mode based on psychrometric conditions, including temperature and humidity.

[0084] FIG. 5 depicts a series of steps **300** involved in operating the evaporative cooling system and its control system. A user can activate the system **305** and enter preferred criteria through a user interface **310**. The criteria can include a temperature, humidity, and fan speed preferences along with input related to energy use (e.g. econ vs. comfort). The system can also include sensors **320** to detect ambient temperature and humidity levels, water temperatures, air pressure and supply air temperature.

[0085] User criteria and data collected from the temperature sensors can be stored and analyzed in a computer or central processing unit. Logic and one or more algorithms **325** can be used to monitor components and the system controls **330**. The system can take efforts to optimize the air temperature of the environment in a gathering area or passenger compartment. For example, the speed of the fan and the position of the chamber separation plate can be adjusted to achieve a desired air or water temperature. Further, water flow can be adjusted with the pump and valves.

[0086] The system can balance economy with a user's desired temperature. An algorithm can analyze ambient conditions to select the most energy efficient cooling

mode for the system to achieve a desired temperature. For example, the system can be set to “max airflow” mode and adjust to the third mode (as depicted in FIG. 3C) in order to maximize the airflow supply. In the alternative, the system can be set to “comfort mode.” The chamber separation plate can be adjusted to the first mode (as depicted in FIG. 3A) and operate with more emphasis on maintaining a desired temperature. The system can also operate in intermediate modes.

Working Example

Use of the Evaporative Cooling System in a Residential Structure

[0087] The evaporative cooling system can be used to condition air inside a residence. While cool air is directed into the residence, warm air from the heat rejection unit can be directed toward the exterior environment. In this example, a user enters desired criteria such as a target temperature into the system. Sensors monitor conditions inside a residence and adjust the system controls.

[0088] The user activates the system through a switch or user interface. Fans drive ambient air through the system. Ambient air enters the system and is cooled with a heat exchange that does not increase the humidity. The next stage includes an evaporative cooling process whereby sensible heat is converted to latent heat through the vaporization of water. Cool air is directed out of the system into a room or other area. Heat and moisture is exhausted into the exterior environment from the system by a heat rejection unit. The heat rejection unit also expels heat from circulating water so that cool water can be fed back into the water system. The evaporative cooling also chills water that circulates through the system. The combination of these conditioning stages provides for outlet supply temperatures to go below the pre-treatment wet bulb temperature without the use of a mechanical vapor compression system.

[0089] A user can adjust the settings to alter the air flow or temperature output of the system. For example, the user may desire a lower output air temperature and can adjust the position of the chamber separation plate. In this example, the plate is initially

placed for operation in the first mode illustrated in FIG. 3A (i.e. below the vertical mid-section and above the intake of the supply fan). This mode increases heat rejection capacity, producing lower output air temperatures while reducing the volumetric air flow rate. Based on an ambient temperature and relative humidity of 32°C and 60% relative humidity (RH), the output (i.e. conditioned) air temperature is expected to be below 24°C.

[0090] In another example, the user desires a slightly higher volumetric output air flow and can adjust the position of the chamber separation plate **150**, according to the second mode illustrated in FIG. 3B (i.e. above the vertical mid-section and below the intake of the exhaust fan). This mode increases the active surface area of the cooling unit and increases volumetric air flow output; conversely, this also reduces heat rejection capacity and moderately increases output air temperatures. Based on an ambient temperature and relative humidity of 32°C and 60%RH, the output (i.e. conditioned) air temperature is expected to be between 24-25°C.

[0091] In another example, the user desires to maximize the volumetric air flow output and can adjust the chamber separation plate **150**, according to the third mode illustrated in FIG. 3C. The plate is set at the top of the unit which seals the exhaust fan with the cooling unit. The system operates in full height capacity of the evaporative porous media. The media provides cooling while the air-water heat exchanger is inactive. This mode of operation is suitable for conditions where ambient humidity is low allowing for a high temperature reduction potential. It provides the largest possible air flow rate and cooling capacity. Further, under this operating mode, the cooling capacity can be further varied by adjusting the speed of the supply fan. Based on an ambient temperature and relative humidity of 32°C and 50%RH, the output (i.e. conditioned) air temperature is expected to be about 25°C.

[0092] The system can also operate in “fan mode” (not shown). This mode can be preferred when ambient air is at a comfortable temperature and conditioning is not necessary or humidity is high so that conditioning is limited. The main fan operates to

draw air and create a draft. The water pump is inactive and as such the heat rejection and main cooling units are inactive. In this mode, the system does not cool incoming air. Rather, it circulates air and consumes less energy than other modes.

[0093] The system can also operate in a “heat rejection mode,” as depicted in FIG. 3D. This mode can be used to exhaust heat from an external source. For example, hot water from a water-cooled apparatus can be directed to the system for heat rejection, thus generating cold water which can be returned for cooling. In this operating mode, only the heat rejection unit is active. The chamber plate **150** is set at the bottom of the unit with air is drawn through the system via the exhaust fan **130**. The hot water is fed directly to a separate internal reservoir tank and pumped to the heat exchanger **160** and the evaporative porous media **140** for water conditioning. There are two levels of water conditioning. The first provides a lower water temperature output and has both the heat exchanger **160** and evaporative porous media **140** active. The second provides a slightly higher water temperature output as only the evaporative porous media **140** active. Selection between the water conditioning levels depends on the rejection heat load, for example, having both components active would be suited for a larger incoming heat load. In the final step, the conditioned water is fed to the main reservoir **180** and can be returned to the water-cooled apparatus.

[0094] It will be appreciated that variations of the above disclosed and other features and functions, or alternatives thereof, may be combined into other systems or applications. Also, various unforeseen or unanticipated alternatives, modifications, variations or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

[0095] Although embodiments of the current disclosure have been described comprehensively, in considerable detail to cover the possible aspects, those skilled in the art would recognize that other versions of the disclosure are also possible.

What is claimed is:

1. A system for cooling air or water, said system comprising:
 - a. a cooling unit;
 - b. a heat rejection unit;
 - c. a water management system comprising a control valve; and
 - d. a chamber separation plate;wherein the cooling unit is comprised of a sensible heat exchanger and an evaporative porous media unit;
wherein the chamber separation plate separates the cooling unit and the heat rejection unit and is movable along a shaft such that its position determines the capacities of the cooling unit and the heat rejection unit.
2. The system of claim 1, wherein a control system maintains a target air and/or water temperature by controlling at least one of fan speed, water circulation and the position of the chamber separation plate.
3. The system of claim 1, wherein the water management system controls the flow of water through at least one of the sensible heat exchanger and the evaporative porous media unit.
4. The system of claim 1, wherein the cooling unit is comprised of multiple sensible heat exchangers or multiple evaporative porous media units.
5. The system of claim 4, wherein the water management system controls the flow of water through at least one of the sensible heat exchangers or the evaporative porous media units.

6. The system of claim 1, wherein the heat rejection unit cools circulating water adiabatically using evaporative porous media.
7. A method of conditioning air and/or water comprising steps of:
 - a. directing ambient air into a cooling unit;
 - b. circulating water through the cooling unit, wherein a water management system comprising a control valve is used to control the flow of circulating water;
 - c. conditioning the ambient air with a sensible heat exchanger and/or with an evaporative porous media unit;
 - d. exhausting warm air with a heat rejection unit; and
 - e. adjusting the position of a chamber separation plate to control the capacities of the cooling unit and the heat rejection unit;wherein the chamber separation plate separates the cooling unit and the heat rejection unit and is movable along a shaft.
8. The method of claim 7, including a step of maintaining a target air and/or water temperature by controlling at least one of fan speed and water circulation.
9. The method of claim 7, wherein the water management system is used to control the flow of water through at least one of the sensible heat exchanger and the evaporative porous media unit.
10. The method of claim 7, including a step of cooling air in a second sensible heat exchanger.
11. The method of claim 10, including a step of cooling air in a second evaporative porous media unit.
12. The method of claim 11, wherein the water management system controls the flow of water through at least one of the sensible heat exchangers and the evaporative porous media units.

13. The method of claim 7, wherein the heat rejection unit cools water adiabatically using evaporative porous media.

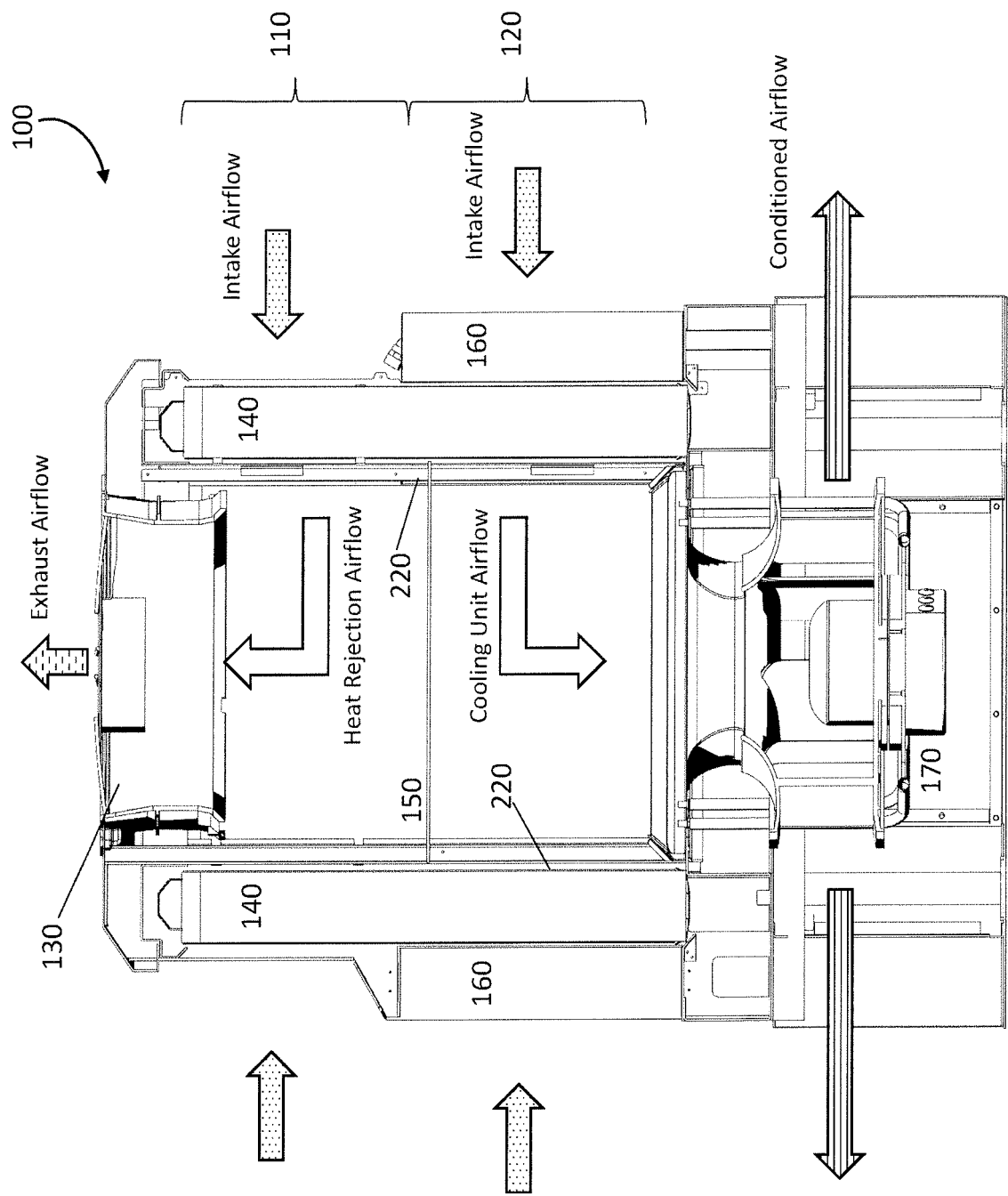


FIG. 1

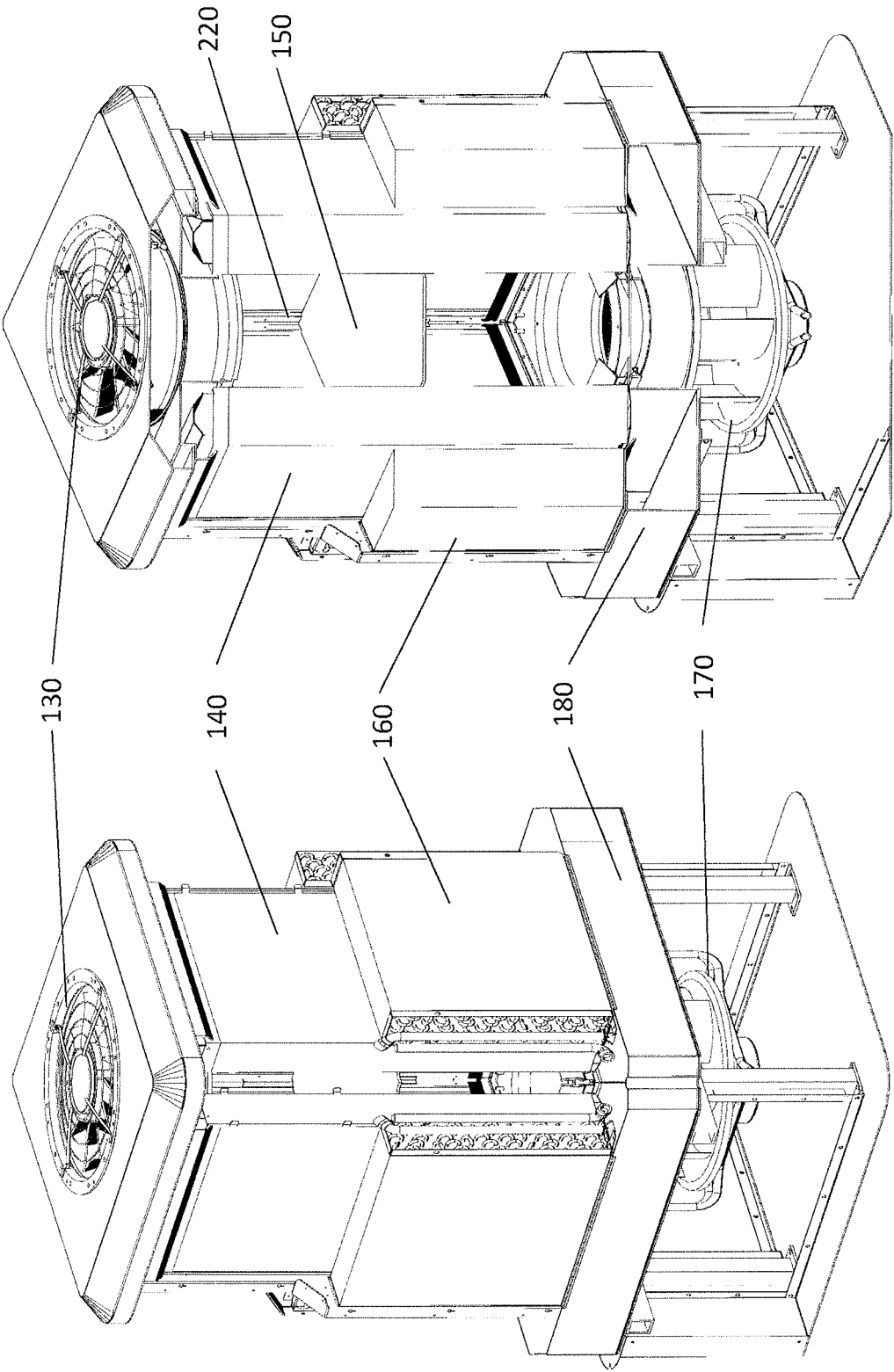


FIG. 2B

FIG. 2A

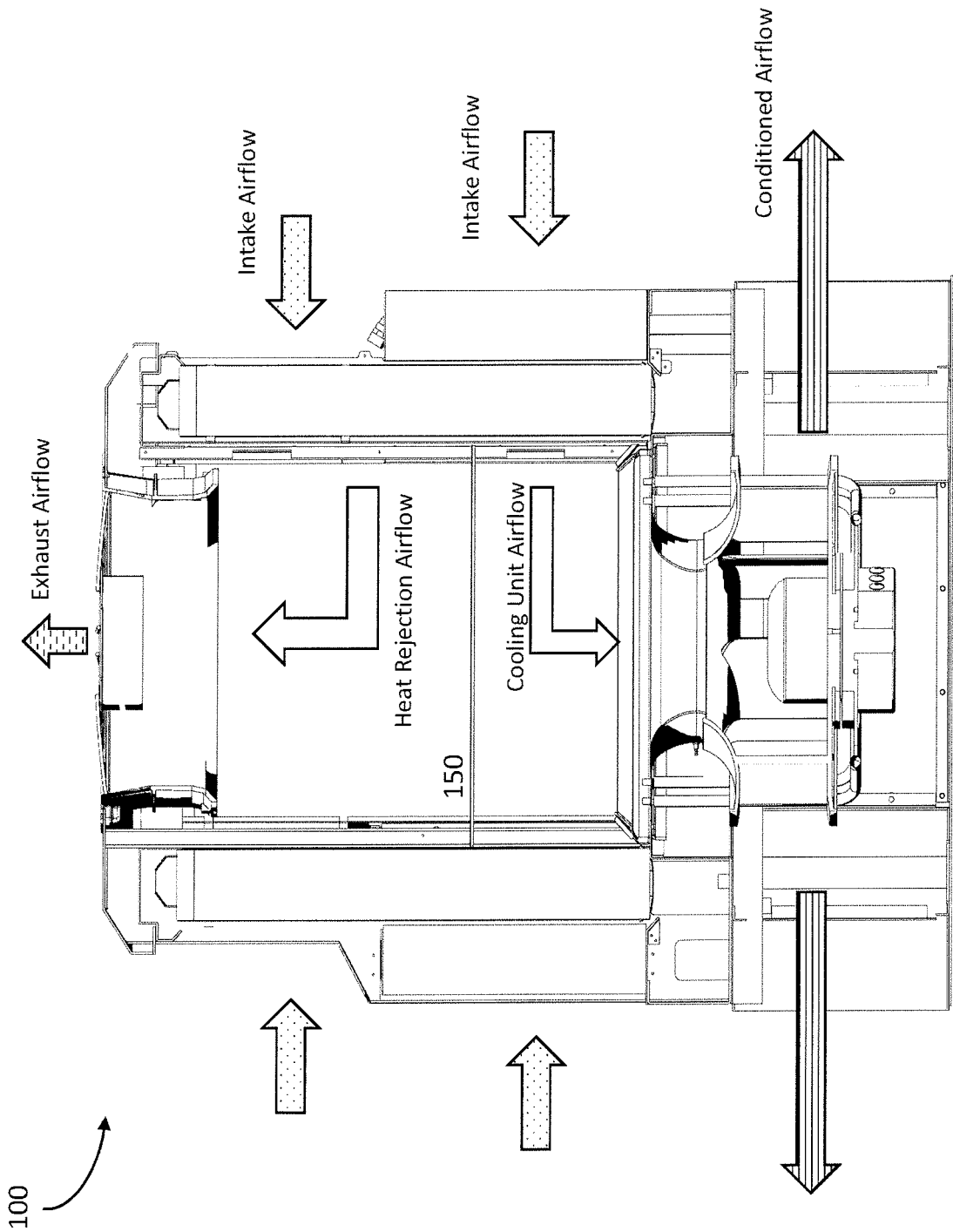


FIG. 3A

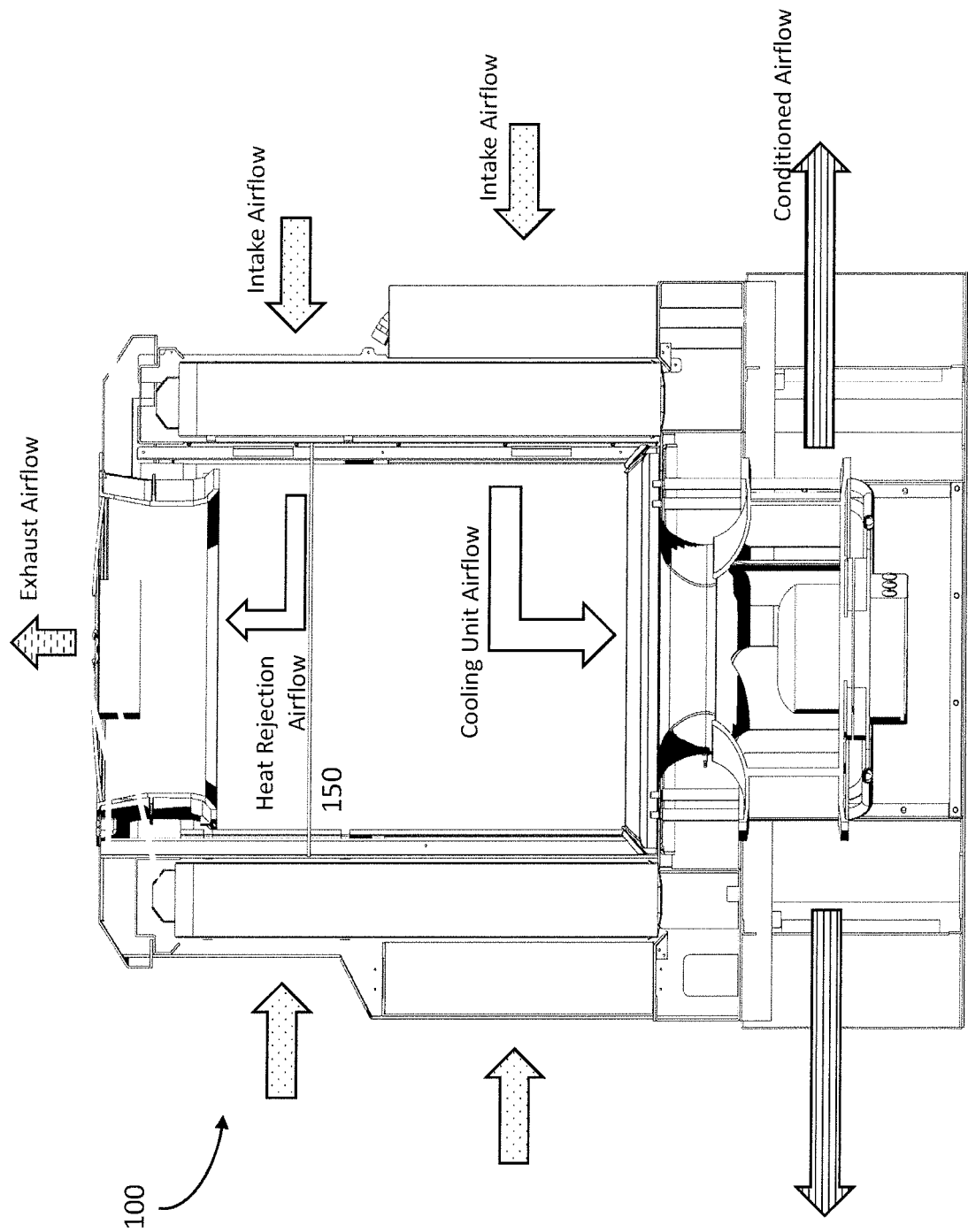


FIG. 3B

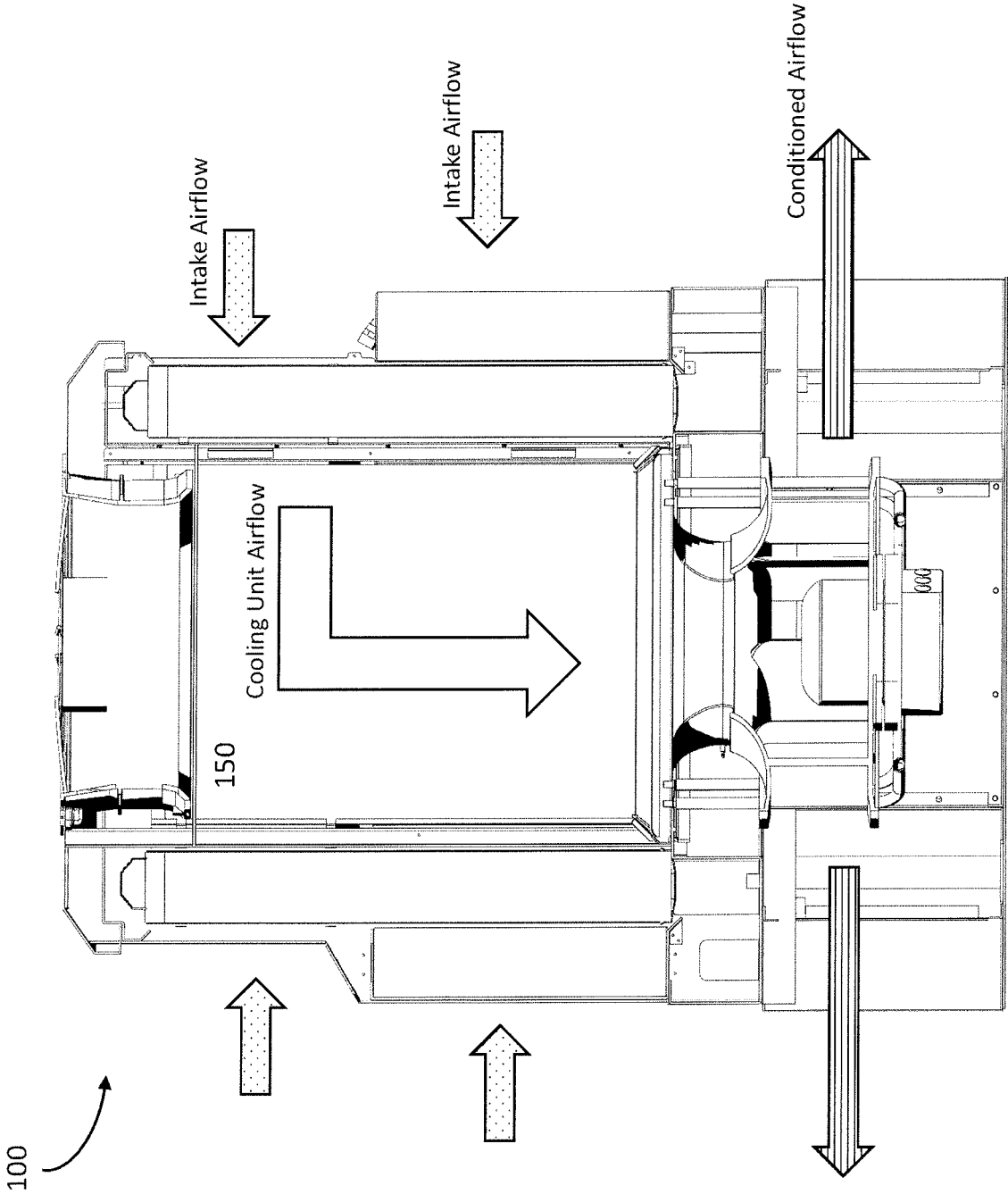


FIG. 3C

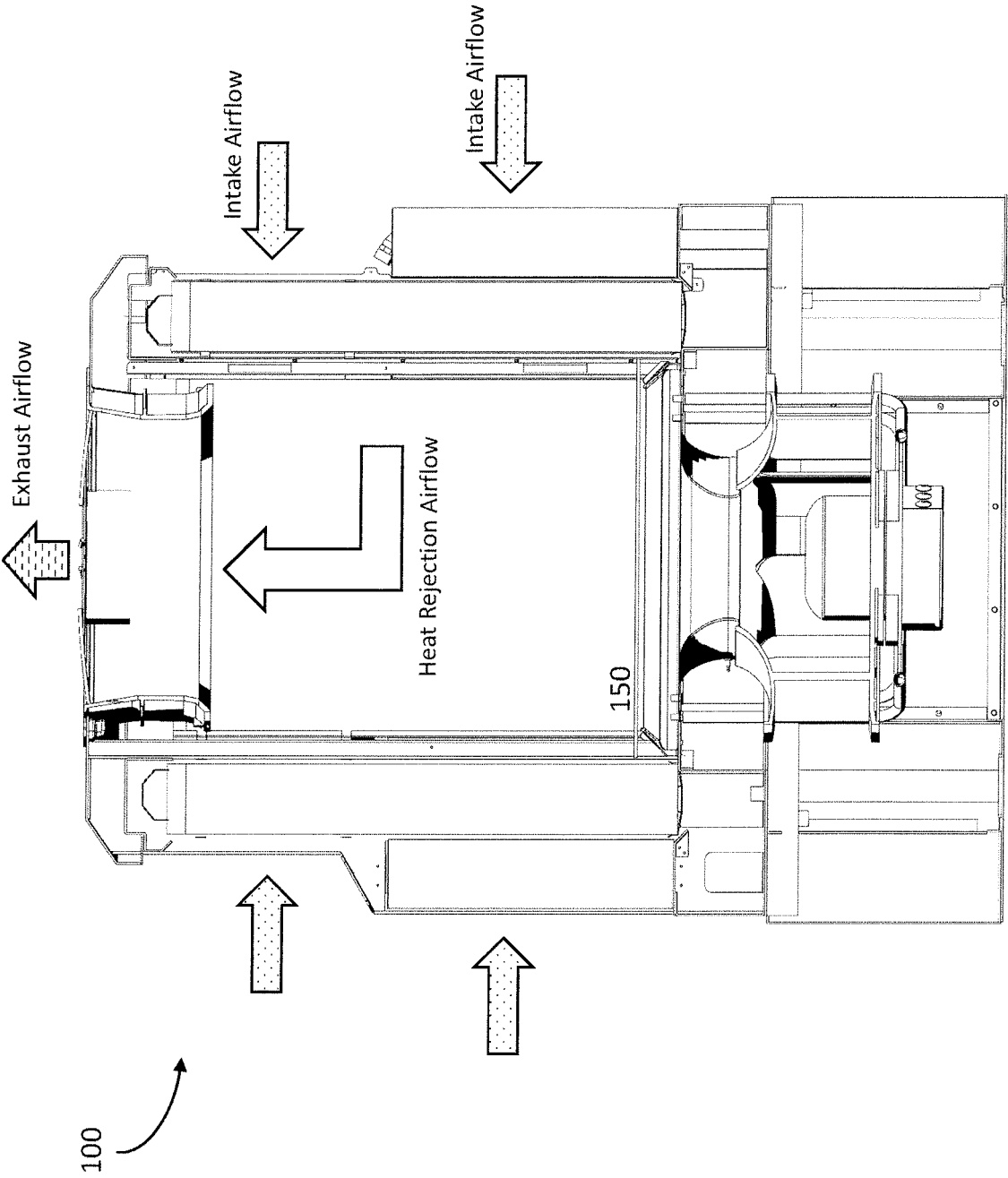


FIG. 3D

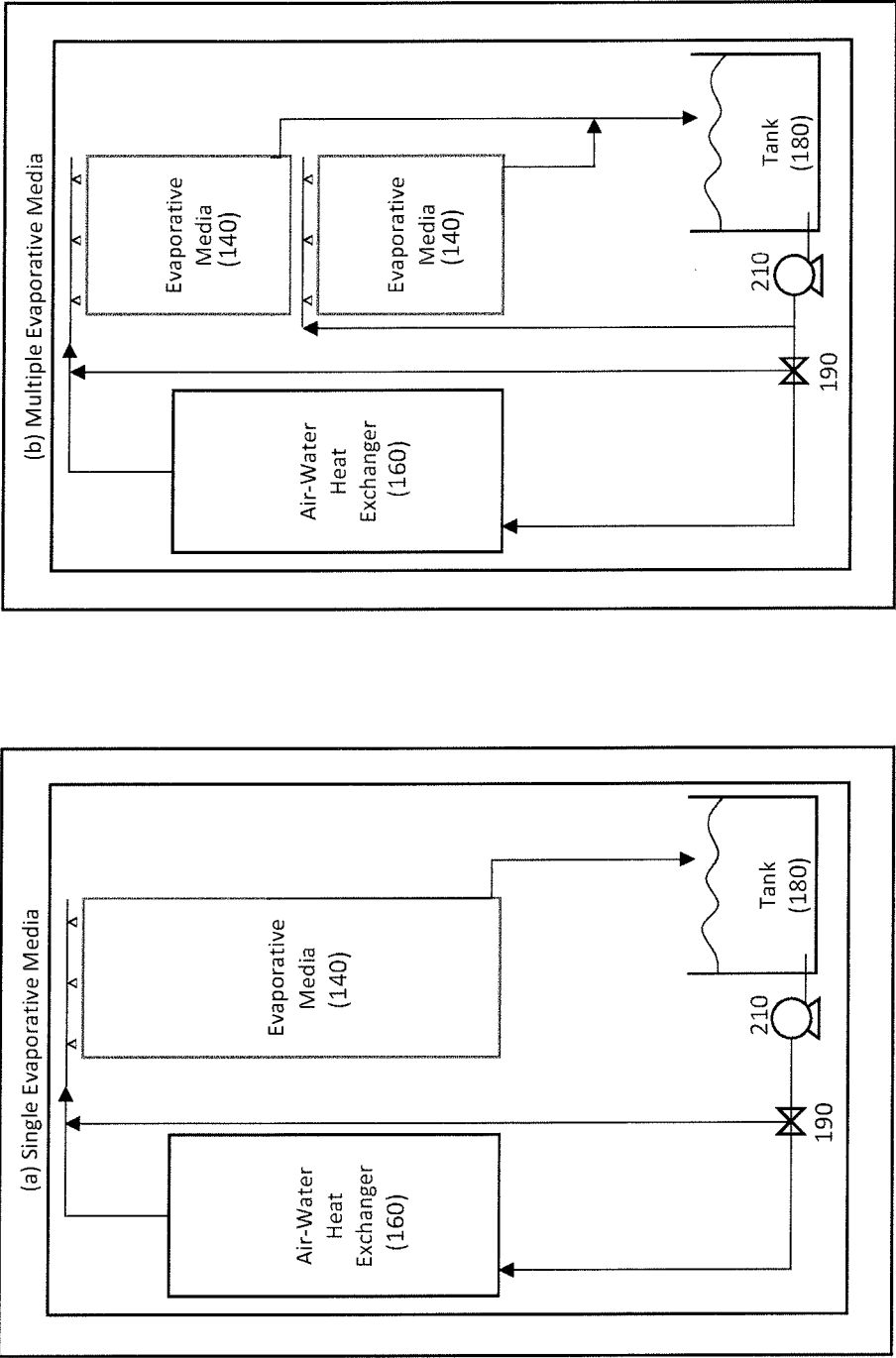


FIG. 4B

FIG. 4A

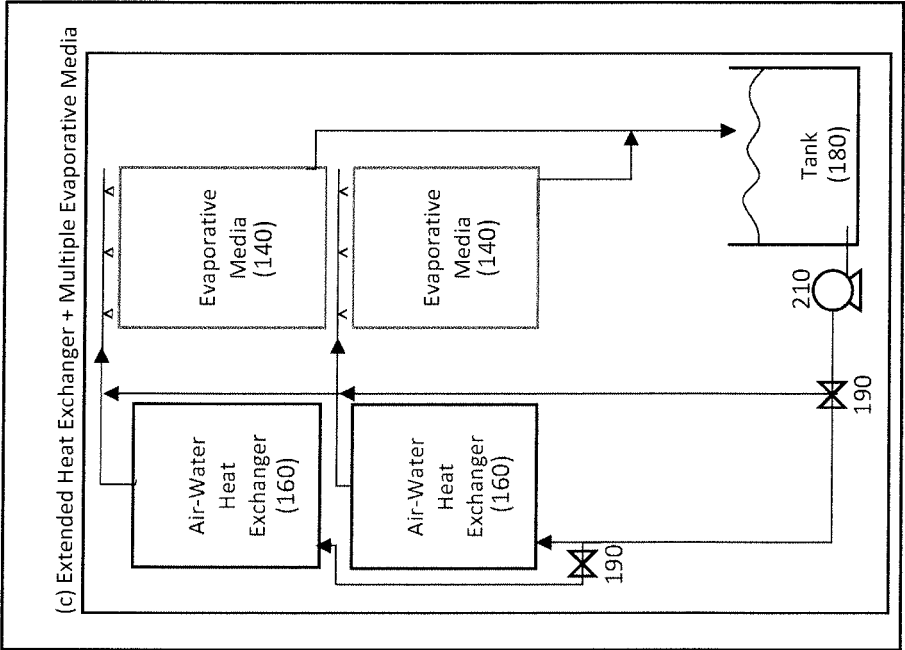


FIG. 4C

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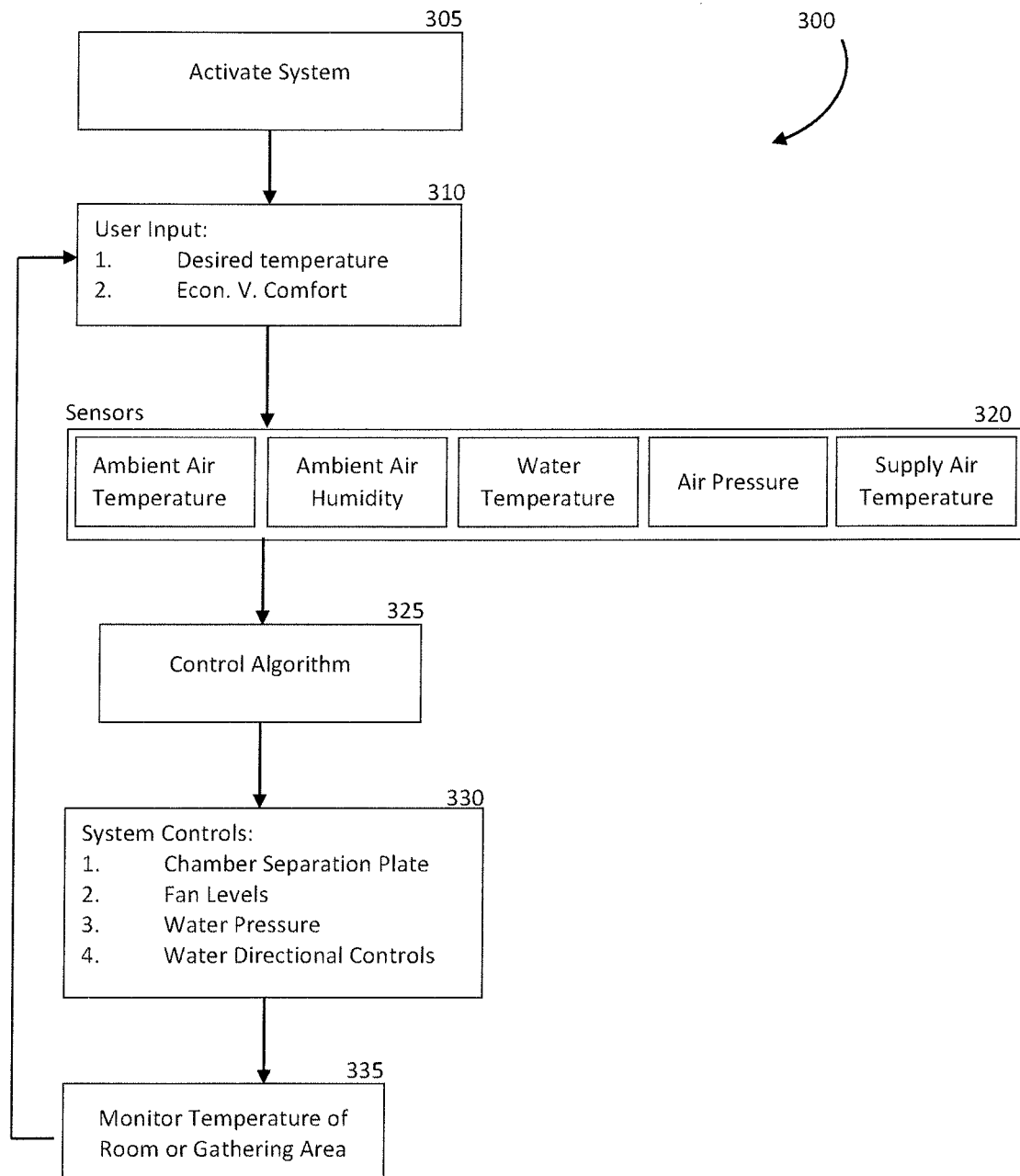


FIG. 5