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(54) **SYSTEM AND METHOD FOR COOLING A SERVER-BASED DATA CENTER WITH SUB-AMBIENT COOLING**

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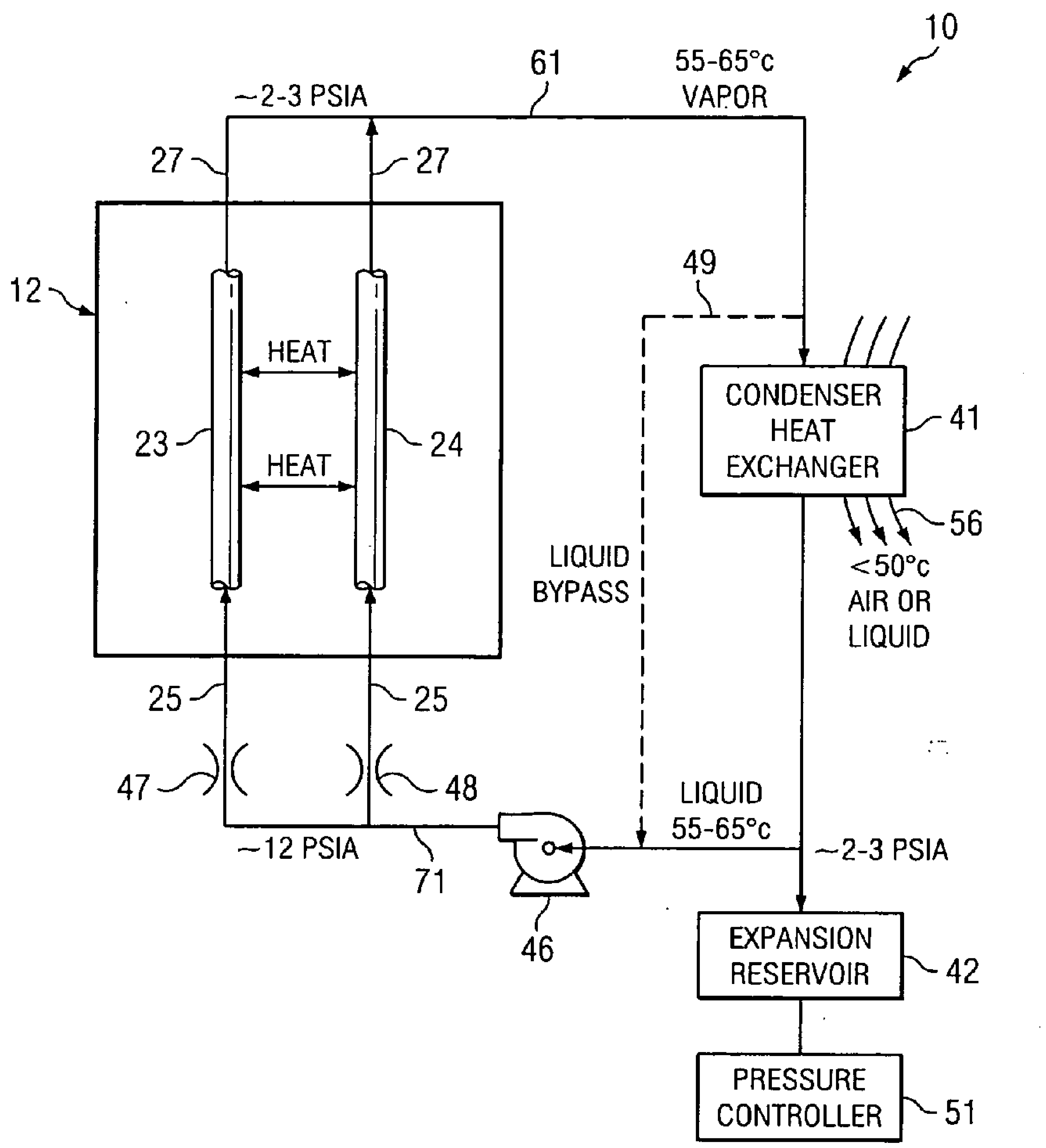
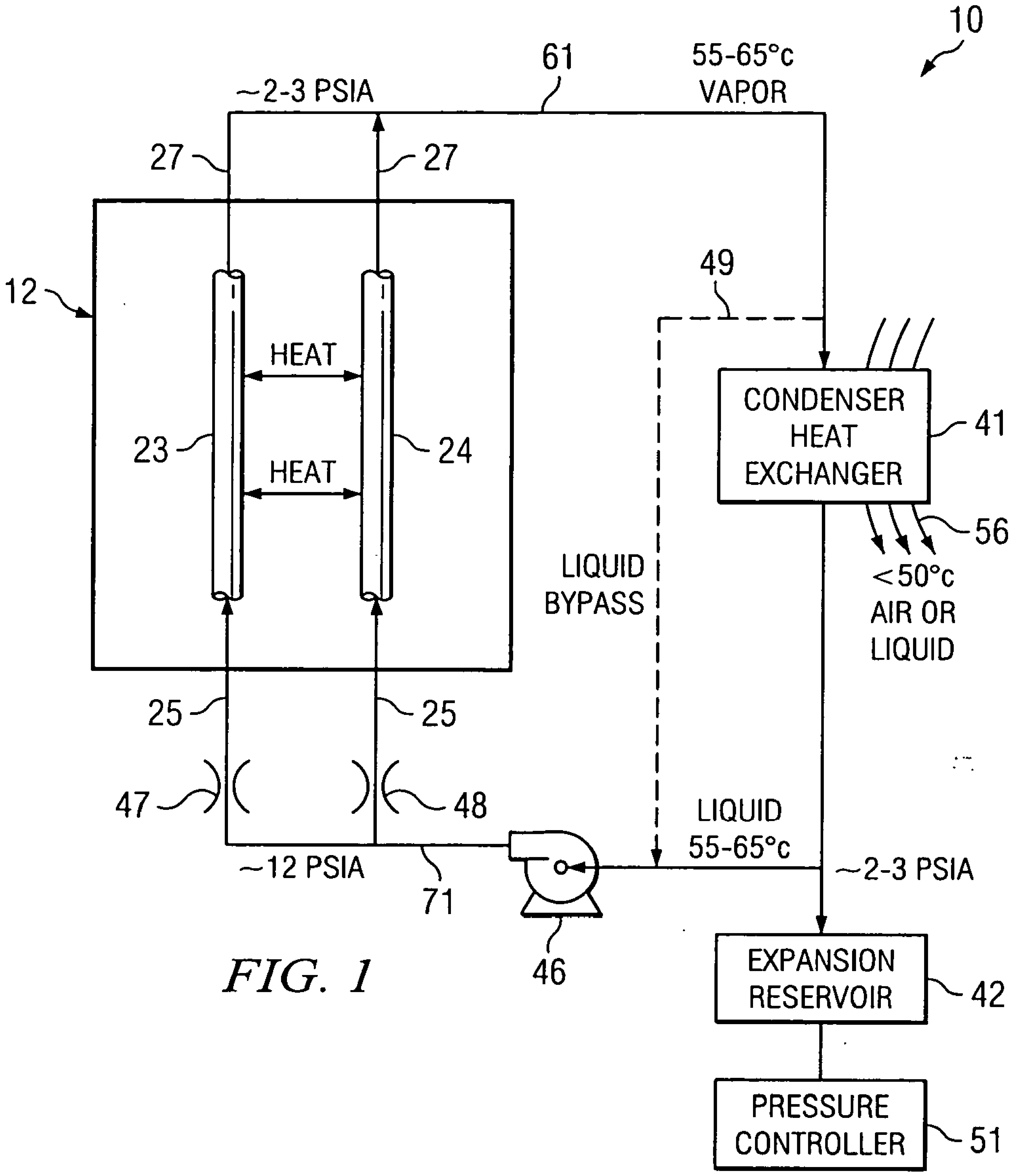
(57) **ABSTRACT**

According to one embodiment of the invention, a cooling system for heat-generating structures comprises a plurality of heat exchangers, a structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers, and a structure which reduces a pressure of the fluid coolant to a pressure at which the fluid coolant has a boiling temperature less than a temperature of the heat-generating structures. Each of the plurality of heat exchangers is in thermal communication with at least one of the heat-generating structures and has an inlet and an outlet. Thermal energy from the heat-generating structure causes the fluid coolant substantially in the form of a liquid to boil and vaporize in each of the plurality of heat exchangers so that the fluid coolant absorbs thermal energy from the heat-generating structure as the fluid coolant changes state.




10
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71
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EXPANSION
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PRESSURE
CONTROLLER
51

FIG. 1

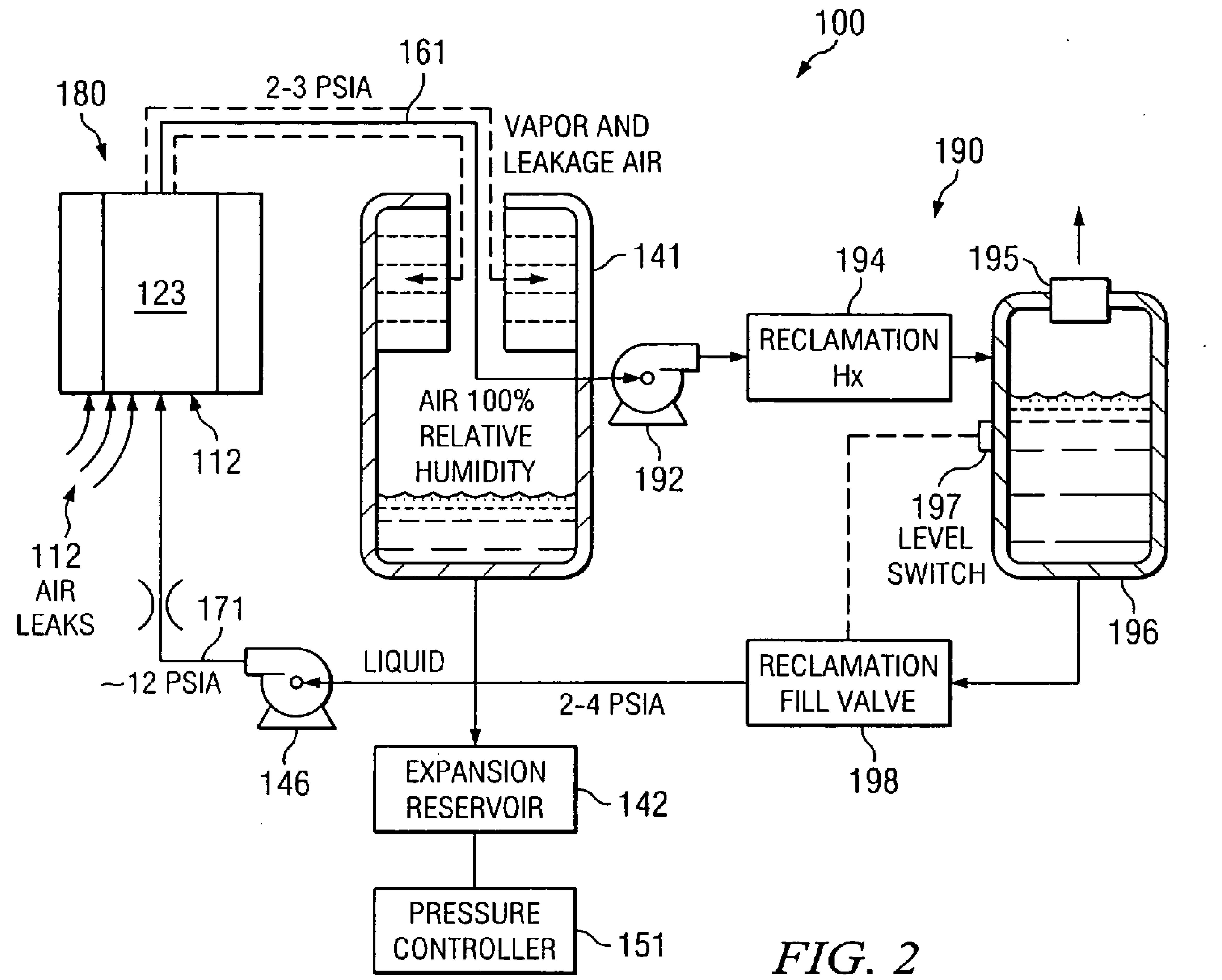


FIG. 2

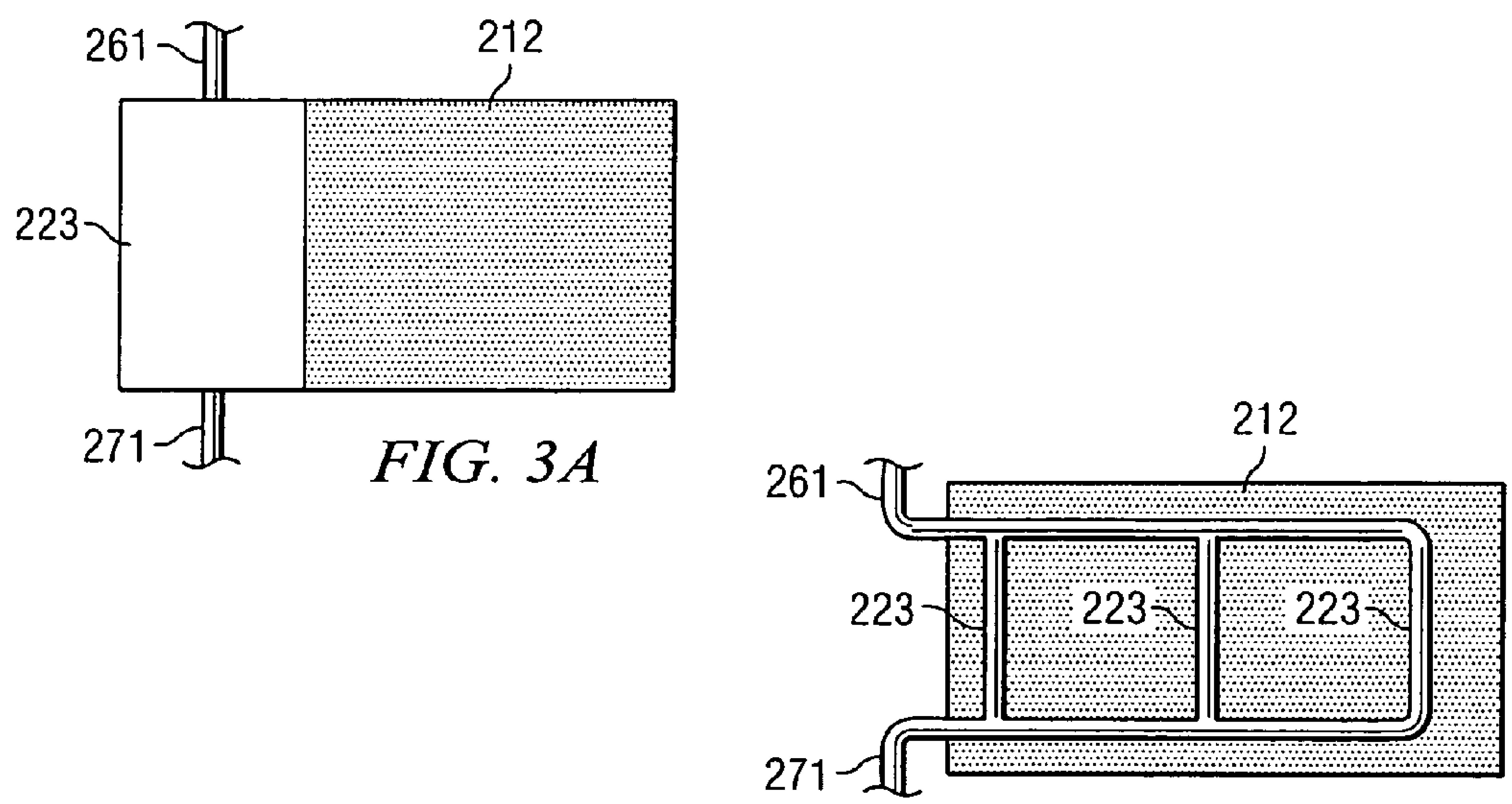


FIG. 3A

FIG. 3B

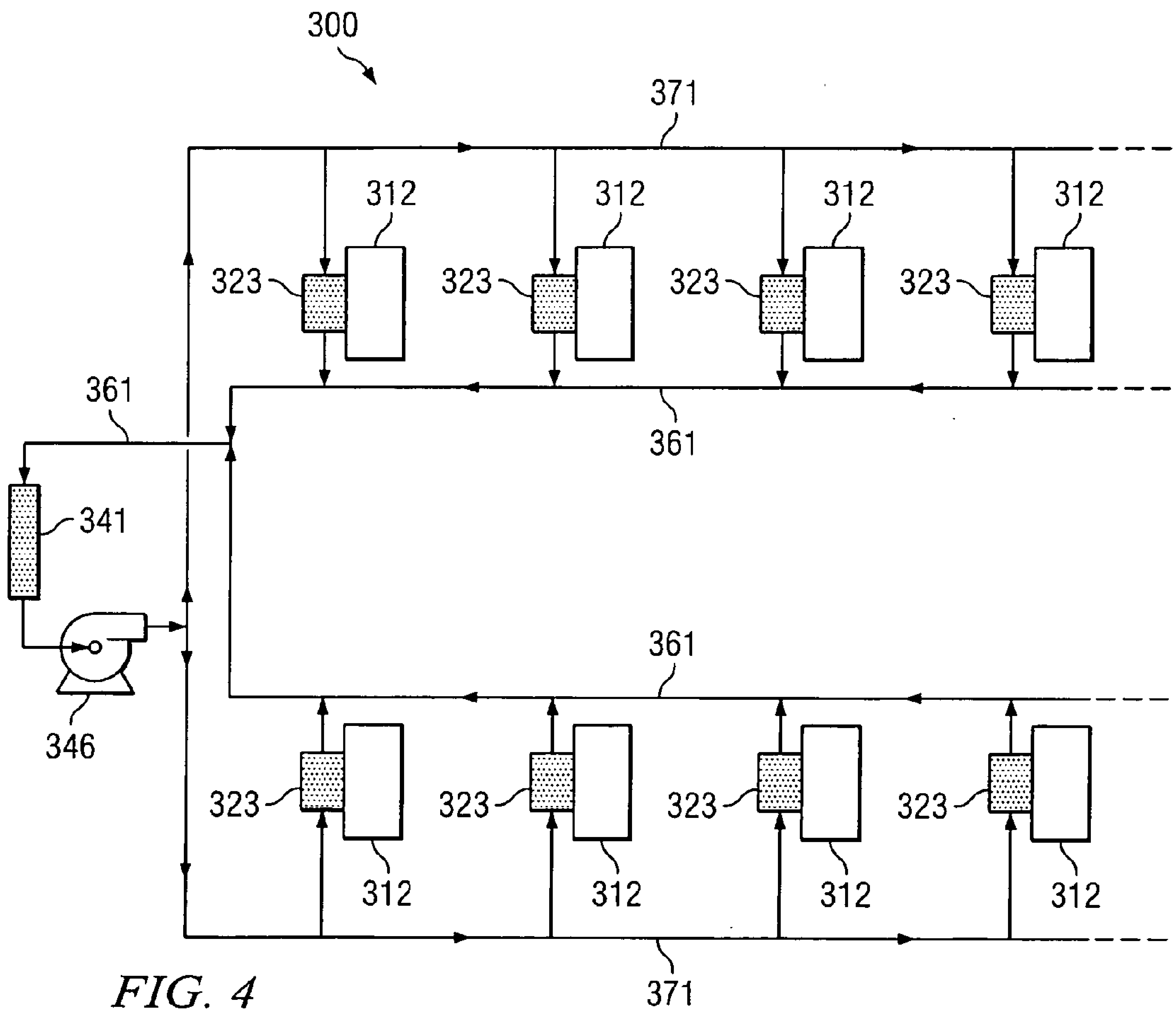
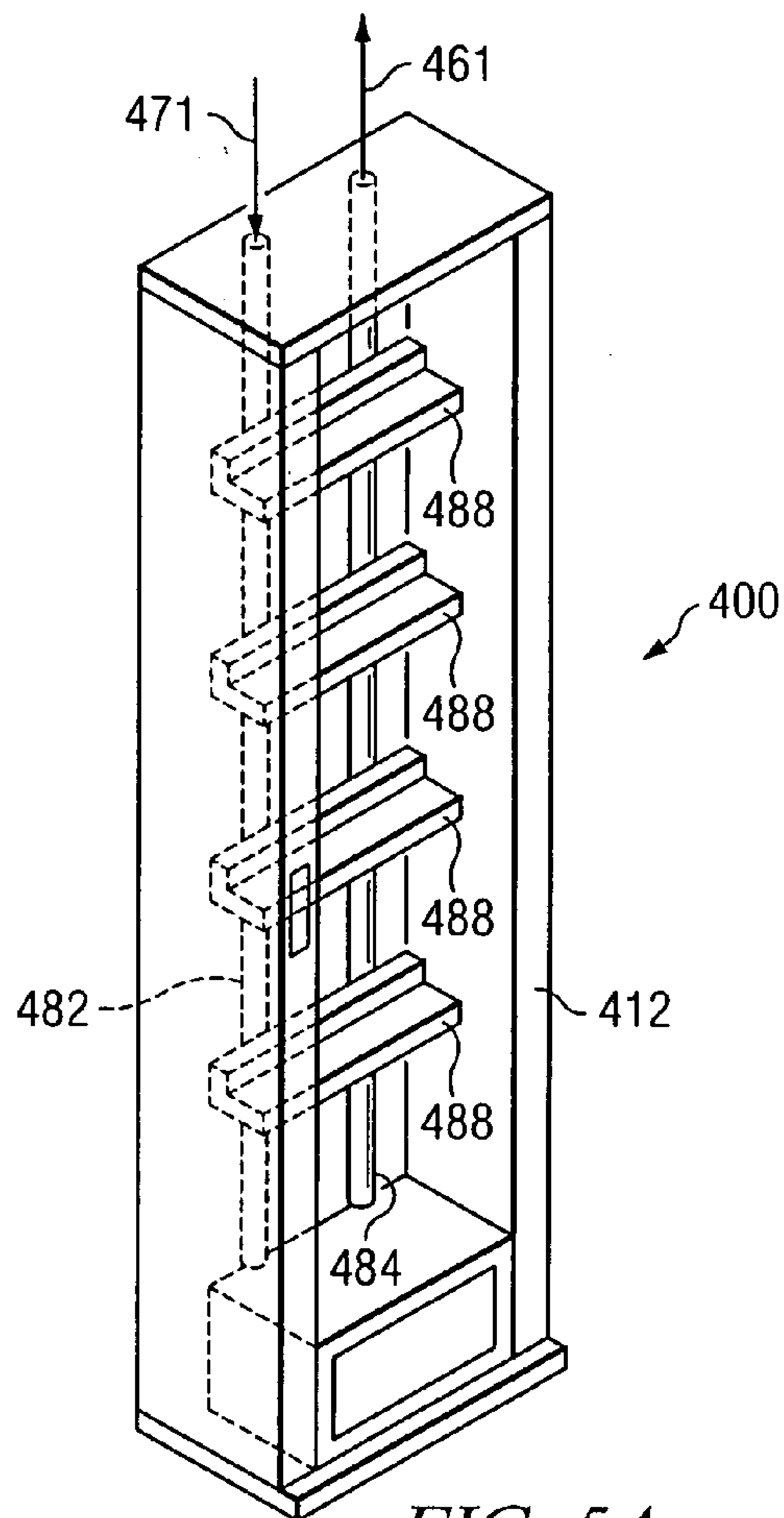


FIG. 4


471
461
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400
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482
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FIG. 5A

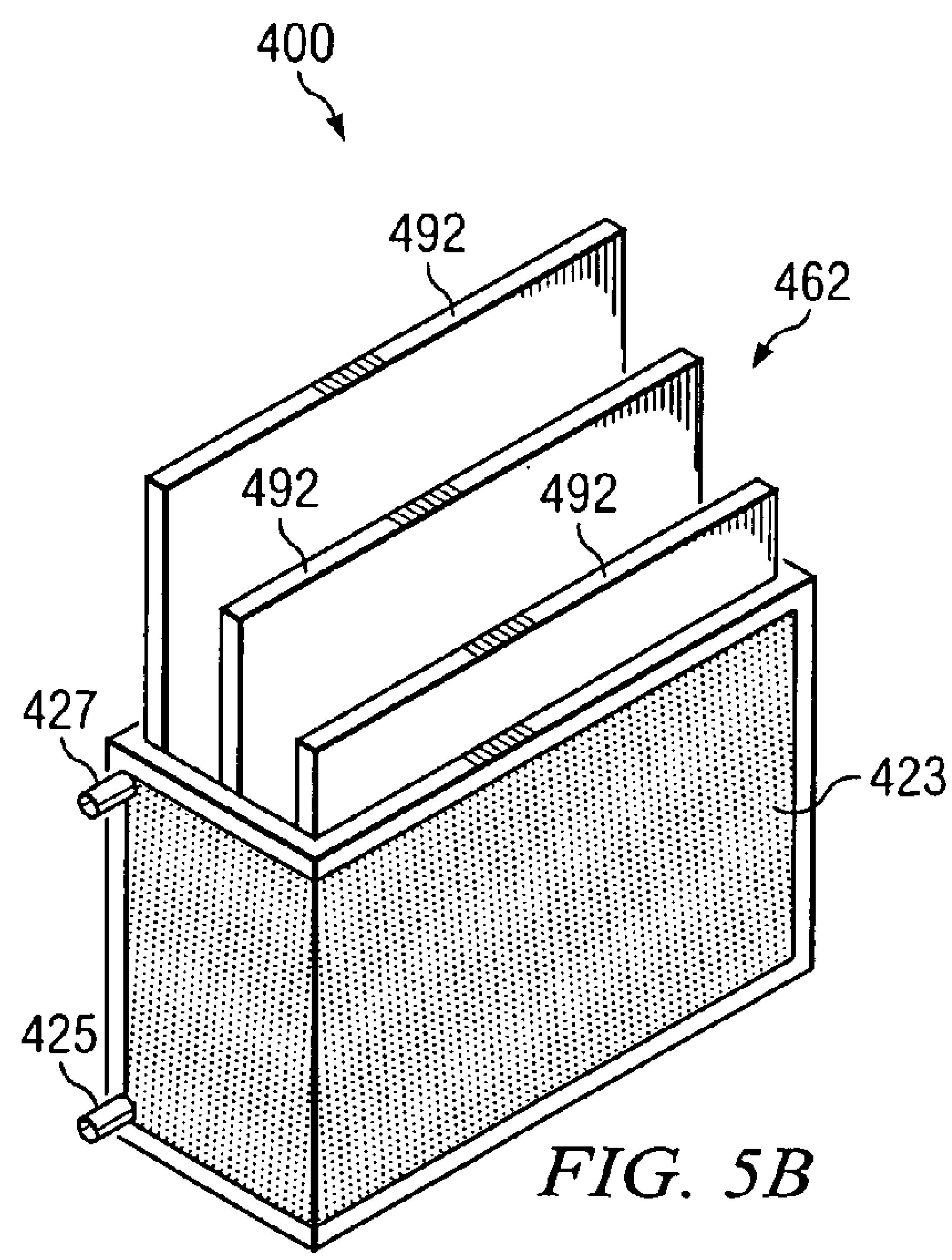
400
492
462
492
492
427
423
425

FIG. 5B

SYSTEM AND METHOD FOR COOLING A SERVER-BASED DATA CENTER WITH SUB-AMBIENT COOLING

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates generally to the field of cooling systems and, more particularly, to a system and method for cooling a server-based data center with sub-ambient cooling.

BACKGROUND OF THE INVENTION

[0002] A variety of different types of structures can generate heat or thermal energy in operation. To prevent such structures from over heating, a variety of different types of cooling systems may be utilized to dissipate the thermal energy, including air conditioning systems.

SUMMARY OF THE INVENTION

[0003] According to one embodiment of the invention, a cooling system for heat-generating structures comprises a plurality of heat exchangers, a structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers, and a structure which reduces a pressure of the fluid coolant to a pressure at which the fluid coolant has a boiling temperature less than a temperature of the heat-generating structures. Each of the plurality of heat exchangers is in thermal communication with at least one of the heat-generating structures and has an inlet and an outlet. Thermal energy from the heat-generating structure causes the fluid coolant substantially in the form of a liquid to boil and vaporize in each of the plurality of heat exchangers so that the fluid coolant absorbs thermal energy from the heat-generating structure as the fluid coolant changes state.

[0004] Certain embodiments of the invention may provide numerous technical advantages. For example, a technical advantage of one embodiment may include the capability to enhance cooling capability for data centers at a reduced energy consumption. Other technical advantages of other embodiments may include the capability to minimize a need for conditioned air in a cooling system. Still yet other technical advantages of other embodiments may include the capability to minimize potential impact on a server upon a leak occurring the in the cooling system.

[0005] Although specific advantages have been enumerated above, various embodiments may include all, some, or none of the enumerated advantages. Additionally, other technical advantages may become readily apparent to one of ordinary skill in the art after review of the following figures and description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] For a more complete understanding of example embodiments of the present invention and its advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

[0007] FIG. **1** is a block diagram of an embodiment of a cooling system that may be utilized in conjunction with other embodiments;

[0008] FIG. **2** is a block diagram of another embodiment of a cooling system that may be utilized in conjunction with other embodiments;

[0009] FIGS. **3**A and **3**B illustrate in a block diagram, a transfer of thermal energy from a structure to a cooling system, according to embodiments of the invention;

[0010] FIG. **4** is a block diagram of a cooling system, according to an embodiment of the invention; and

[0011] FIGS. **5**A and **5**B illustration a sub-system for transfer of thermal energy from a structure to a cooling system, according to an embodiment of the invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

[0012] It should be understood at the outset that although example embodiments of the present invention are illustrated below, the present invention may be implemented using any number of techniques, whether currently known or in existence. The present invention should in no way be limited to the example embodiments, drawings, and techniques illustrated below, including the embodiments and implementation illustrated and described herein. Additionally, the drawings are not necessarily drawn to scale.

[0013] Conventional server based data centers are usually cooled with refrigerated air. The American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE) has suggested organizing server cabinets in rows with cool conditioned-air in the spaces between every second row. The cool air is drawn through the front of the cabinets to cool the interior electronics and then blown out the back and toward the ceiling where it is exhausted. Further, ASHRAE papers have suggested the use of heat pipes to concentrate the heat and loop-thermosyphons to take the heat to the top of individual cabinets. The heat or thermal energy is then removed from the top of the individual cabinet by the cool conditioned-air.

[0014] Difficulties can arise with such configurations. For a modern data center, which could be on the order of 40,000 square feet (having, for example, 1,300 server cabinets), the cooling needs could be on the order of 1,000 tons (3513 kW) of refrigeration, including the ancillary cooling loads (lighting, fan heat, UPS, etc.). To meet these cooling needs, the refrigerated air cooling system may require two 500 ton chillers with variable speed compressors and forty 30 ton chilled water computer room air-conditioning units. In other words, these systems requires a lot of energy consumption. Accordingly, teachings of some embodiments of the invention recognize a cooling system that efficiently enhances cooling capability for data centers at a reduced energy consumption. Additionally, teachings of some embodiments of the invention recognize a cooling system that minimizes a need for conditioned air. Further, teachings of some embodiments of the invention recognize a configuration that minimizes impact on a server upon a leak occurring in the cooling system.

[0015] FIG. **1** is a block diagram of an embodiment of a cooling system **10** that may be utilized in conjunction with other embodiments disclosed herein, namely the embodiments described with reference to FIGS. **3**-**5**B. Although the details of one cooling system will be described below, it should be expressly understood that other cooling systems may be used in conjunction with embodiments of the invention, including the cooling system **100**, described with reference to FIG. **2**.

[0016] The cooling system **10** of FIG. **1** is shown cooling a structure **12** that is exposed to or generates thermal energy. The structure **12** may be any of a variety of structures, including, but not limited to, electronic components, circuits, computers, and servers. Because the structure **12** can vary greatly, the details of structure **12** are not illustrated and described. The cooling system **10** of FIG. **1** includes a vapor line **61**, a liquid line **71**, heat exchangers **23** and **24**, a pump **46**, inlet orifices **47** and **48**, a condenser heat exchanger **41**, an expansion reservoir **42**, and a pressure controller **51**.

[0017] The structure **12** may be arranged and designed to conduct heat or thermal energy to the heat exchangers **23**, **24**. To receive this thermal energy or heat, the heat exchanger **23**, **24** may be disposed on an edge of the structure **12** (e.g., as a thermosyphon, heat pipe, or other device) or may extend through portions of the structure **12**, for example, through a thermal plane of structure **12**. In particular embodiments, the heat exchangers **23**, **24** may extend up to the components of the structure **12**, directly receiving thermal energy from the components. Although two heat exchangers **23**, **24** are shown in the cooling system **10** of FIG. **1**, one heat exchanger or more than two heat exchangers may be used to cool the structure **12** in other cooling systems.

[0018] In operation, a fluid coolant flows through each of the heat exchangers **23**, **24**. As discussed later, this fluid coolant may be a two-phase fluid coolant, which enters inlet conduits **25** of heat exchangers **23**, **24** in liquid form. Absorption of heat from the structure **12** causes part or all of the liquid coolant to boil and vaporize such that some or all of the fluid coolant leaves the exit conduits **27** of heat exchangers **23**, **24** in a vapor phase. To facilitate such absorption or transfer of thermal energy, the heat exchangers **23**, **24** may be lined with pin fins or other similar devices which, among other things, increase surface contact between the fluid coolant and walls of the heat exchangers **23**, **24**. Additionally, in particular embodiments, the fluid coolant may be forced or sprayed into the heat exchangers **23**, **24** to ensure fluid contact between the fluid coolant and the walls of the heat exchangers **23**, **24**.

[0019] The fluid coolant departs the exit conduits **27** and flows through the vapor line **61**, the condenser heat exchanger **41**, the expansion reservoir **42**, a pump **46**, the liquid line **71**, and a respective one of two orifices **47** and **48**, in order to again to reach the inlet conduits **25** of the heat exchanger **23**, **24**. The pump **46** may cause the fluid coolant to circulate around the loop shown in FIG. **1**. In particular embodiments, the pump **46** may use magnetic drives so there are no shaft seals that can wear or leak with time. Although the vapor line **61** uses the term “vapor” and the liquid line **71** uses the terms “liquid”, each respective line may have fluid in a different phase. For example, the liquid line **71** may have contain some vapor and the vapor line **61** may contain some liquid.

[0020] The orifices **47** and **48** in particular embodiments may facilitate proper partitioning of the fluid coolant among the respective heat exchanger **23**, **24** , and may also help to create a large pressure drop between the output of the pump **46** and the heat exchanger **23**, **24** in which the fluid coolant vaporizes. The orifices **47** and **48** may have the same size, or may have different sizes in order to partition the coolant in a proportional manner which facilitates a desired cooling profile.

[0021] A flow **56** of fluid (either gas or liquid) may be forced to flow through the condenser heat exchanger **41**, for example by a fan (not shown) or other suitable device. In particular embodiments, the flow **56** of fluid may be ambient fluid. The condenser heat exchanger **41** transfers heat from the fluid coolant to the flow **56** of ambient fluid, thereby causing any portion of the fluid coolant which is in the vapor phase to condense back into a liquid phase. In particular embodiments, a liquid bypass **49** may be provided for liquid fluid coolant that either may have exited the heat exchangers **23**, **24** or that may have condensed from vapor fluid coolant during travel to the condenser heat exchanger **41**. In particular embodiments, the condenser heat exchanger **41** may be a cooling tower.

[0022] The liquid fluid coolant exiting the condenser heat exchanger **41** may be supplied to the expansion reservoir **42**. Since fluids typically take up more volume in their vapor phase than in their liquid phase, the expansion reservoir **42** may be provided in order to take up the volume of liquid fluid coolant that is displaced when some or all of the coolant in the system changes from its liquid phase to its vapor phase. The amount of the fluid coolant which is in its vapor phase can vary over time, due in part to the fact that the amount of heat or thermal energy being produced by the structure **12** will vary over time, as the structure **12** system operates in various operational modes.

[0023] Turning now in more detail to the fluid coolant, one highly efficient technique for removing heat from a surface is to boil and vaporize a liquid which is in contact with a surface. As the liquid vaporizes in this process, it inherently absorbs heat to effectuate such vaporization. The amount of heat that can be absorbed per unit volume of a liquid is commonly known as the latent heat of vaporization of the liquid. The higher the latent heat of vaporization, the larger the amount of heat that can be absorbed per unit volume of liquid being vaporized.

[0024] The fluid coolant used in the embodiment of FIG. **1** may include, but is not limited to, mixtures of antifreeze and water or water, alone. In particular embodiments, the antifreeze may be ethylene glycol, propylene glycol, methanol, or other suitable antifreeze. In other embodiments, the mixture may also include fluoroinert. In particular embodiments, the fluid coolant may absorb a substantial amount of heat as it vaporizes, and thus may have a very high latent heat of vaporization.

[0025] Water boils at a temperature of approximately 100° C. at an atmospheric pressure of 14.7 pounds per square inch absolute (psia). In particular embodiments, the fluid coolant’s boiling temperature may be reduced to between 55-65° C. by subjecting the fluid coolant to a subambient pressure of about 2-3 psia. Thus, in the cooling system **10** of FIG. **1**, the orifices **47** and **48** may permit the pressure of the fluid coolant downstream from them to be substantially less than the fluid coolant pressure between the pump **46** and the orifices **47** and **48**, which in this embodiment is shown as approximately 12 psia. In some embodiments, the pressure controller **51** maintains the coolant at a pressure of approximately 2-7 psia along the portion of the loop which extends from the orifices **47** and **48** to the pump **46**, in particular through the heat exchangers **23** and **24**, the condenser heat exchanger **41**, and the expansion reservoir **42**. In particular embodiments, a metal bellows may be used in the expansion reservoir **42**, connected to the loop using brazed joints. In particular embodiments, the pressure controller **51** may control loop pressure by using a motor driven linear actuator that is part of the metal bellows of the expansion reservoir **42** or by using small gear pump to evacuate the loop to the desired pressure level. The fluid coolant removed may be stored in the metal bellows whose fluid connects are brazed. In other configurations, the pressure controller **51** may utilize other suitable devices capable of controlling pressure.

[0026] In particular embodiments, the fluid coolant flowing from the pump **46** to the orifices **47** and **48** through liquid line **71** may have a temperature of approximately 55° C. to 65° C. and a pressure of approximately 12 psia as referenced above. After passing through the orifices **47** and **48**, the fluid coolant may still have a temperature of approximately 55° C. to 65° C., but may also have a lower pressure in the range about 2 psia to 3 psia. Due to this reduced pressure, some or all of the fluid coolant will boil or vaporize as it passes through and absorbs heat from the heat exchanger **23** and **24**.

[0027] After exiting the exits ports **27** of the heat exchanger **23**, **24**, the subambient coolant vapor travels through the vapor line **61** to the condenser heat exchanger **41** where heat or thermal energy can be transferred from the subambient fluid coolant to the flow **56** of fluid. The flow **56** of fluid in particular embodiments may have a temperature of less than 50° C. In other embodiments, the flow **56** may have a temperature of less than 40° C. As heat is removed from the fluid coolant, any portion of the fluid which is in its vapor phase will condense such that substantially all of the fluid coolant will be in liquid form when it exits the condenser heat exchanger **41**. At this point, the fluid coolant may have a temperature of approximately 55° C. to 65° C. and a subambient pressure of approximately 2 psia to 3 psia. The fluid coolant may then flow to pump **46**, which in particular embodiments **46** may increase the pressure of the fluid coolant to a value in the range of approximately 12 psia, as mentioned earlier. Prior to the pump **46**, there may be a fluid connection to an expansion reservoir **42** which, when used in conjunction with the pressure controller **51**, can control the pressure within the cooling loop.

[0028] It will be noted that the embodiment of FIG. **1** may operate without a refrigeration system. In the context of electronic circuitry, such as may be utilized in the structure **12**, the absence of a refrigeration system can result in a significant reduction in the size, weight, and power consumption of the structure provided to cool the circuit components of the structure **12**.

[0029] FIG. **2** is a block diagram of another embodiment of a cooling system **100** that may be utilized in conjunction with other embodiments disclosed herein, namely the embodiments described with reference to FIGS. **3**-**5**B. The cooling system **100** of FIG. **2** may operate in a similar manner to the cooling system **10** of FIG. **1**; however, the cooling system **100** of FIG. **2** also incorporates an air removal system **190**. For a variety of reasons, unintended air or other fluids may be introduced into the cooling system **100**. For example, in embodiments operating at sub-ambient pressure, outside ambient fluid will tend to leak into the sub-ambient system upon a presence of a leak in the system—that is, from a higher to lower pressure. Accordingly the cooling system **100** may utilize the air removal system **190** to remove air or other fluids from the cooling system **100**. The air removal system **190** in the embodiment of FIG. **2** includes an air pump **192**, a reclamation heat exchanger **194**, an air trap **196**, and a reclamation fill valve **198**.

[0030] With reference to FIG. **2**, the cooling loop for the cooling system **100** is similar to the cooling loop for the cooling system **10** of FIG. **1** for example, including a heat exchanger **123**, a pump **160**, a liquid line **171**, a vapor line **161**, an expansion reservoir **142**, a pressure controller **151**, and a condenser heat exchanger **141**. However, fluid or air leaks **102** may enter the system at the heat exchanger **123** of a structure **112** or other location and travel in the vapor line **161** to the condenser heat exchanger **141**. At the condenser heat exchanger **141**, condensed coolant liquid may pass though while air (and any associated coolant vapor that may be present therein) may be pumped using air pump **192** to a reclamation heat exchanger **194**. The reclamation heat exchanger **194** may cool the air/coolant vapor combination, which condenses the vapor from the air stream being removed from the bottom of the condenser heat exchanger **141**. Coolant separates from the air in a trap **196** while the air exits through a vent **195**. A level switch **197** may be in communication with a reclamation fill valve **198** to allow the reclamation fill valve **198** to open when recovered coolant is present. The recovered coolant may be reintroduced to the loop through the reclamation fill valve **198** and a conduit in communication with the pump **146**.

[0031] Although one example of an air removal system **190** has been shown with reference to FIG. **2**, other air removal systems may be used in other embodiments of the invention with more, less, or alternative component parts. Additionally, although components of embodiments of cooling system **10** and **100** have been shown in FIGS. **1** and **2**, it should be understood that other embodiments of the cooling system **10** can include more, fewer, or different component parts. For example, although specific temperatures and pressures have been described for such one embodiment of the cooling systems **10** and **100**, other embodiments of the cooling system **10** and **100** may operate at different pressures and temperatures. Additionally, in some embodiments a coolant fill port and/or a coolant bleed port may be utilized with metal-to-metal caps to seal them. Further, in some embodiments, all or a portion of the joints between various components may be brazed, soldered or welded using metal-to-metal seal caps. Further, in some embodiments, as opposed to utilizing a reclamation heat exchanger **194**, the air/coolant vapor combination may simply be vented to the atmosphere.

[0032] FIGS. **3**A and **3**B illustrate in a block diagram, a transfer of thermal energy from a structure **212** to a cooling system, according to embodiments of the invention. In FIG. **3**A, the heat exchanger **223** has been disposed on an end of a structure **212**. In such embodiments, the heat exchanger **223** may be a thermosyphon, heat pipe, or other similar device. Although not expressly shown, the structure **212** may include a variety of features to enhance transfer of thermal energy to the heat exchanger **223**. Fluid is received in a substantially liquid state through a liquid line **271** and vaporized in the heat exchanger **223**. The fluid exits the heat exchanger **223** in a substantially vapor state to the vapor line **261**.

[0033] In FIG. **3**B, a plurality of heat exchangers **223** extend through the structure **212** to enhance a transfer of thermal energy. In each of the heat exchangers, fluid is received in a substantially liquid state through a liquid line **271** and vaporized in the heat exchanger **223**. The fluid exits the heat exchanger **223** in a substantially vapor state to the vapor line **261**.

[0034] FIG. **4** is a block diagram of a cooling system **300**, according to an embodiment of the invention. The cooling loop for the cooling system **300** may operate in a similar manner to the cooling loops for the cooling system **10** of FIG. **1** and the cooling system **100** of FIG. **2**, for example, including a heat exchanger **323**, a pump **346**, a liquid line **371**, a vapor line **361**, and a condenser heat exchanger **341**. The cooling system **300** may be used to cool a plurality of structures **312**, for example, servers in a data center.

[0035] In operation, components of the each of servers or structures **312** may generate thermal energy, which is dissipated to the heat exchanger **312**. Each of the heat exchangers **323** of the servers or structures **312** may interact with a common liquid line **371** and a common vapor line **361**. Each of the heat exchangers **323** receives fluid in a substantially liquid state through the liquid line **371** and vaporizes the fluid in the heat exchanger **323**. The fluid exits the heat exchanger **323** in a substantially vapor state to the vapor line **361**.

[0036] As briefly referenced above in FIGS. 3A and 3B, the heat exchangers **323** in some embodiments may be disposed on an end of the server or structure **312**, for example, as a thermosyphon, heat pipe, or other similar device. In other embodiments, the heat exchangers **323** may extend into a portion of the structures **312** to enhance a transfer of thermal energy. In either of these embodiments, the server or structures **312** may include a variety of different features to enhance transfer of thermal energy to the heat exchangers **323**.

[0037] In particular embodiments, the servers or structures **312** may be located inside a building while the condenser heat exchanger **341** and/or pump **346** may be located outside of a building.

[0038] FIGS. **5**A and **5**B illustration a sub-system **400** for transfer of thermal energy from a structure **412** to a cooling system, according to an embodiment of the invention. The sub-system **400** of FIGS. **5**A and **5**B may be used in conjunction with the cooling systems **10**, **100**, and **300** of FIGS. **1**, **2**, and **4**, or other cooling systems. The structure **412** is shown as a server tower, which may hold a plurality of circuit cards assemblies **492** and their associated chassis **462** on shelves **488** or other suitable components. The sub-system **400** includes a liquid manifold line **482** in communication with a liquid line **471** of a cooling system and a vapor manifold line **484** in communication with a vapor line **461** of a cooling system. To deliver liquid coolant and receive vapor coolant, the liquid manifold line **482** and vapor manifold line **484** may be arranged in a variety of configurations. In particular embodiments, the liquid manifold line **482** and vapor manifold line **484** may be vertically disposed in a rear portion of the rack **480**.

[0039] One or more electronic chassis **462** may respectively be plugged into the liquid manifold line **482** and the vapor manifold line **484** to obtain cooling functionality for the electronic chassis **462**. The chassis **462** may have a heat exchanger **423** in its wall, which contains an inlet port **425** (e.g., for substantial liquid fluid coolant) and an exit port **427** (e.g., for substantially vapor fluid coolant) . The inlet port **425** may fluidly couple to the liquid manifold line **482** and the exit port **427** may fluidly couple to the vapor manifold line **484** using a variety of fluid coupling techniques, including but not limited to techniques which utilize seals, O-rings, and other devices.

[0040] Although the chassis **462** has been described as fluidly coupling to the liquid manifold line **482** and the vapor manifold line **484** in the structure **412** in this embodiment, in other embodiments, the structure **412** may provide a series of coolant channels or heat exchangers plumbed into the walls of the rack **412**, for example, in a manner similar to that described with reference to FIG. 3B. Accordingly, each chassis **462** would simply slide into its allocated slot where it may be coupled or clamped to the coolant channels or heat exchangers. An advantage of such an embodiment is that the cooling system may be sealed. Accordingly, minimized perturbances to such a sealed system would occur during insertion or removal of a chassis **462**.

[0041] Although the present invention has been described with several embodiments, a myriad of changes, variations, alterations, transformations, and modifications may be suggested to one skilled in the art, and it is intended that the present invention encompass such changes, variations, alterations, transformation, and modifications as they fall within the scope of the appended claims.

What is claimed is:

1. A cooling system for heat-generating structures disposed in an environment having an ambient pressure, the cooling system comprising:

a structure which reduces a pressure of a fluid coolant to a subambient pressure at which the fluid coolant has a boiling temperature less than a temperature of the heat-generating structures;

a plurality of heat exchangers, each of the plurality of heat exchangers in thermal communication with at least one of the heat-generating structures, each of the plurality of heat exchangers having an inlet and an outlet, each respective inlet operable to receive fluid coolant into the respective heat exchangers substantially in the form of a liquid, and each respective outlet operable to dispense of fluid coolant out of the respective heat exchanger substantially in the form of a vapor;

a structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers, thermal energy from the heat-generating structure causing the fluid coolant substantially in the form of a liquid to boil and vaporize in each of the plurality of heat exchangers so that the fluid coolant absorbs thermal energy from the heat-generating structure as the fluid coolant changes state; and

a structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers.

2. The cooling system of claim 1, further comprising:

a condensing heat exchanger fluidly coupled between the structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers and the structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers, the condensing heat exchange operable to condense the fluid coolant substantially in the form of a vapor into the fluid coolant substantially in the form of a liquid.

3. The cooling system of claim 2, wherein the condensing heat exchanger is a water tower.

4. The cooling system of claim 1, wherein the heat-generating structures are servers.

5. The cooling system of claim 1, wherein the fluid is water.

6. The cooling system of claim 1, wherein at least some of the plurality of heat-exchangers are removably coupleable to the structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers and to the structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers.

7. The cooling system of claim 1, wherein

the heat-generating structures include thermosyphons that receive the thermal-energy from the heat generating structures, and

the plurality of heat exchangers are operable to receive the thermal energy from the thermosyphons.

8. The cooling system of claim 1, further comprising:

a plurality of heat exchangers for at least one of the heat-generating structures;

a liquid manifold line coupled to each of the plurality of heat exchangers for the at least one of the heat-generating structures, the liquid manifold line operable to:

receive fluid coolant from the structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers, and

direct flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers for the at least one of the heat-generating structures;

a vapor manifold line coupled to each of the plurality of heat exchangers for the at least one of the heat-generating structures, the liquid vapor line operable to:

receive flow of fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers for the at least one of the heat-generating structures, and

direct flow of the fluid coolant substantially in the form of a vapor to the structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers.

9. The cooling system of claim 8, wherein the plurality of heat exchangers are removeably coupleable to the liquid manifold line and the vapor manifold line.

10. A cooling system for heat-generating structures, the cooling system comprising:

a plurality of heat exchangers, each of the plurality of heat exchangers in thermal communication with at least one of the heat-generating structures, each of the plurality of heat exchangers having an inlet and an outlet, each respective inlet operable to receive fluid coolant into the respective heat exchangers substantially in the form of a liquid, and each respective outlet operable to dispense fluid coolant out of the respective heat exchanger substantially in the form of a vapor; and

a structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers, thermal energy from the heat-generating structure causing the fluid coolant substantially in the form of a liquid to boil and vaporize in each of the plurality of heat exchangers so that the fluid coolant absorbs thermal energy from the heat-generating structure as the fluid coolant changes state.

11. The cooling system of claim 10, further comprising:

a structure which reduces a pressure of the fluid coolant to a pressure at which the fluid coolant has a boiling temperature less than a temperature of the heat-generating structures.

12. The cooling system of claim 11, wherein the heat-generating structures are disposed in an environment having an ambient pressure and the pressure of the fluid coolant is reduced to a subambient pressure.

13. The cooling system of claim 10, further comprising:

a structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers.

14. The cooling system of claim 13, further comprising:

a condensing heat exchanger fluidly coupled between the structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers and the structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers, the condensing heat exchange operable to condense the fluid coolant substantially in the form of a vapor into the fluid coolant substantially in the form of a liquid.

15. The cooling system of claim 13, further comprising:

a plurality of heat exchangers for at least one of the heat-generating structures;

a liquid manifold line coupled to each of the plurality of heat exchangers for the at least one of the heat-generating structures, the liquid manifold line operable to:

receive fluid coolant from the structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers, and

direct flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers for the at least one of the heat-generating structures;

a vapor manifold line coupled to each of the plurality of heat exchangers for the at least one of the heat-generating structures, the liquid vapor line operable to:

receive flow of fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers for the at least one of the heat-generating structures, and

direct flow of the fluid coolant substantially in the form of a vapor to the structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers.

16. The cooling system of claim 13, wherein at least some of the plurality of heat-exchangers are removably coupleable to the structure which directs flow of the fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers and to the structure which receives flow of the fluid coolant substantially in the form of a vapor from each of the plurality of heat exchangers.

17. A method for cooling heat-generating structures, the method comprising:

providing a plurality of heat exchangers, each of the plurality of heat exchangers in thermal communication with at least one of the heat-generating structures, each of the plurality of heat exchangers having an inlet and an outlet, each respective inlet operable to receive fluid coolant into the respective heat exchangers substantially in the form of a liquid, and each respective outlet operable to dispense of fluid coolant out of the respective heat exchanger substantially in the form of a vapor;

reducing a pressure of the fluid coolant to a pressure at which the fluid coolant has a boiling temperature less than a temperature of the heat-generating structure; and

bringing, through a structure, the fluid coolant into thermal communication with each of the plurality of heat exchangers, so that the fluid coolant absorbs heat from each of the plurality of heat exchangers.

18. The cooling system of claim 17, wherein the heat-generating structures are disposed in an environment having an ambient pressure and the pressure of the fluid coolant is reduced to a subambient pressure.

19. The method of claim 17, further comprising:

providing a plurality of heat exchangers for at least one of the heat-generating structures;

receiving, at a liquid manifold line coupled to each of the plurality of heat exchangers for the at least one of the heat-generating structures, the fluid coolant substantially in the form of a liquid; and

directing, from the liquid manifold line, fluid coolant substantially in the form of a liquid to each of the plurality of heat exchangers for the at least one of the heat-generating structures.

20. The method of claim 17, wherein the plurality of heat exchangers are removably coupleable from the structure.

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