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(54) **COOLING DEVICE, COOLING SYSTEM, AND AUXILIARY COOLING DEVICE FOR DATACENTER**

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CPC ***H05K 7/2079*** (2013.01)

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USPC 62/259.2, 333, 335, 305, 506, 434; 165/104.21, 104.33
See application file for complete search history.

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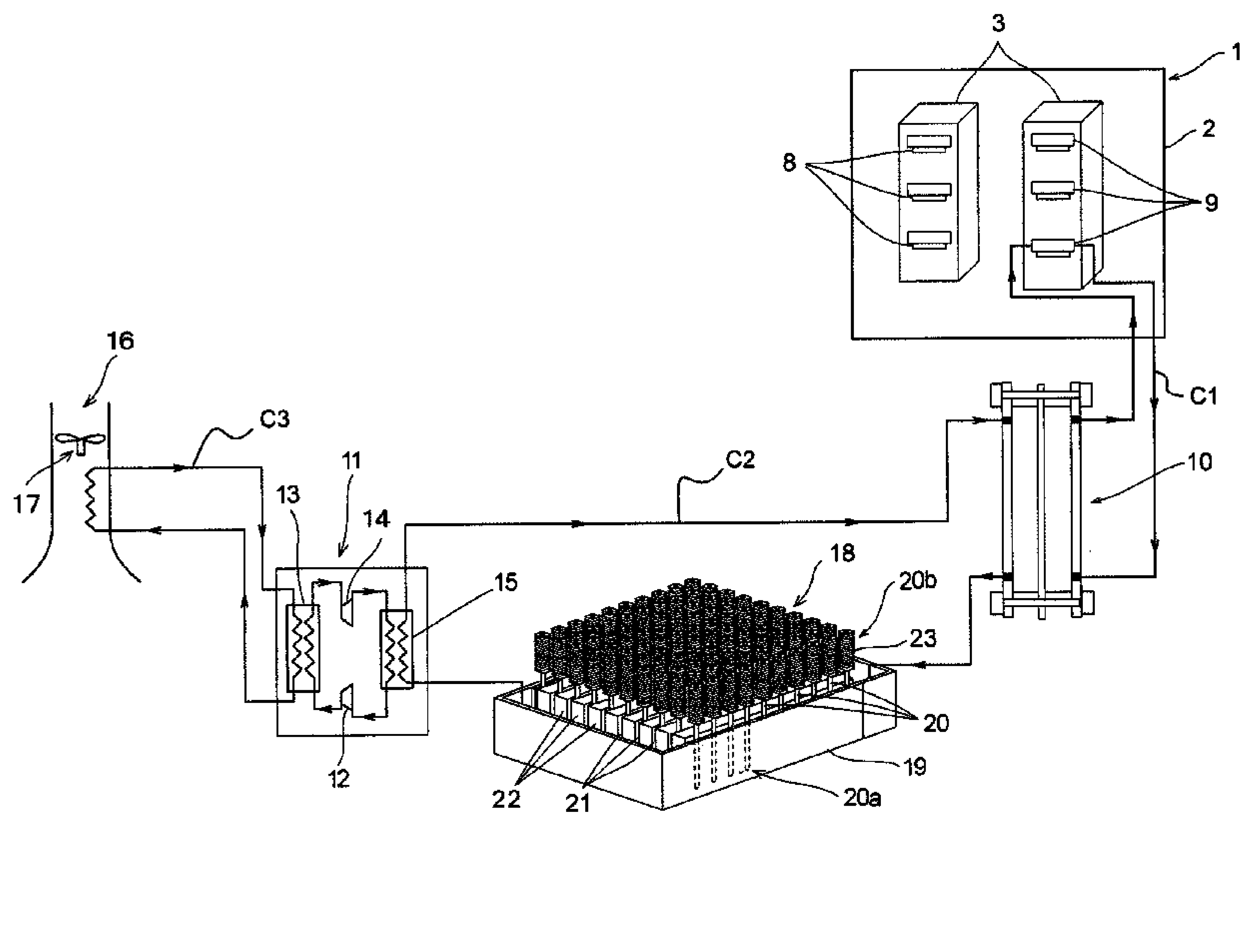
(57) **ABSTRACT**

A cooling system for a data center is provided, in which a plurality of servers having exothermic electronic components is installed in a housing. The cooling system includes: a cooling circuit, a main cooling device to cool a cooling medium heated by electronic components, and an auxiliary cooling device to assist the main cooling device in cooling the cooling medium.

23 Claims, 17 Drawing Sheets



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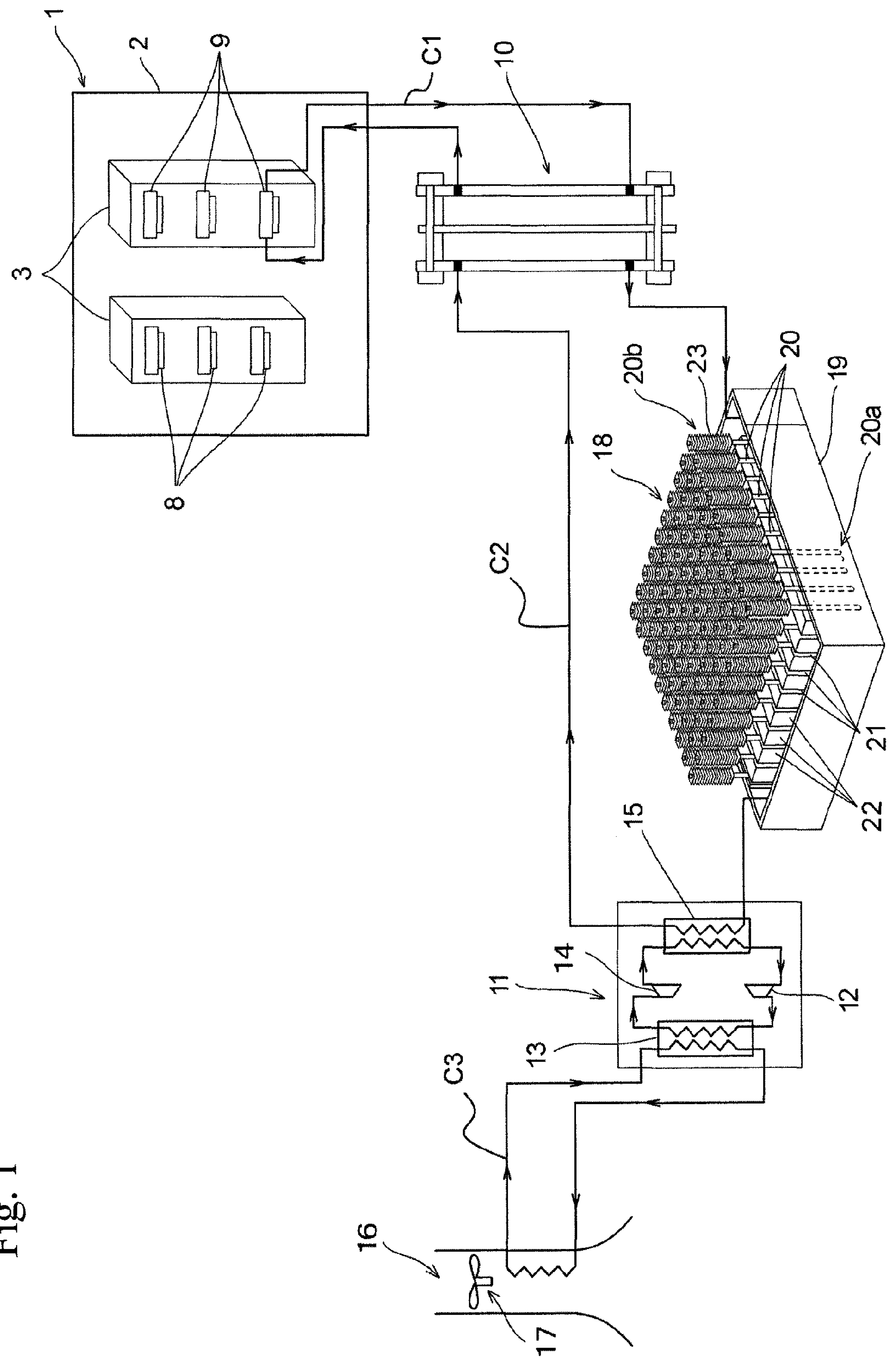

Fig. 1

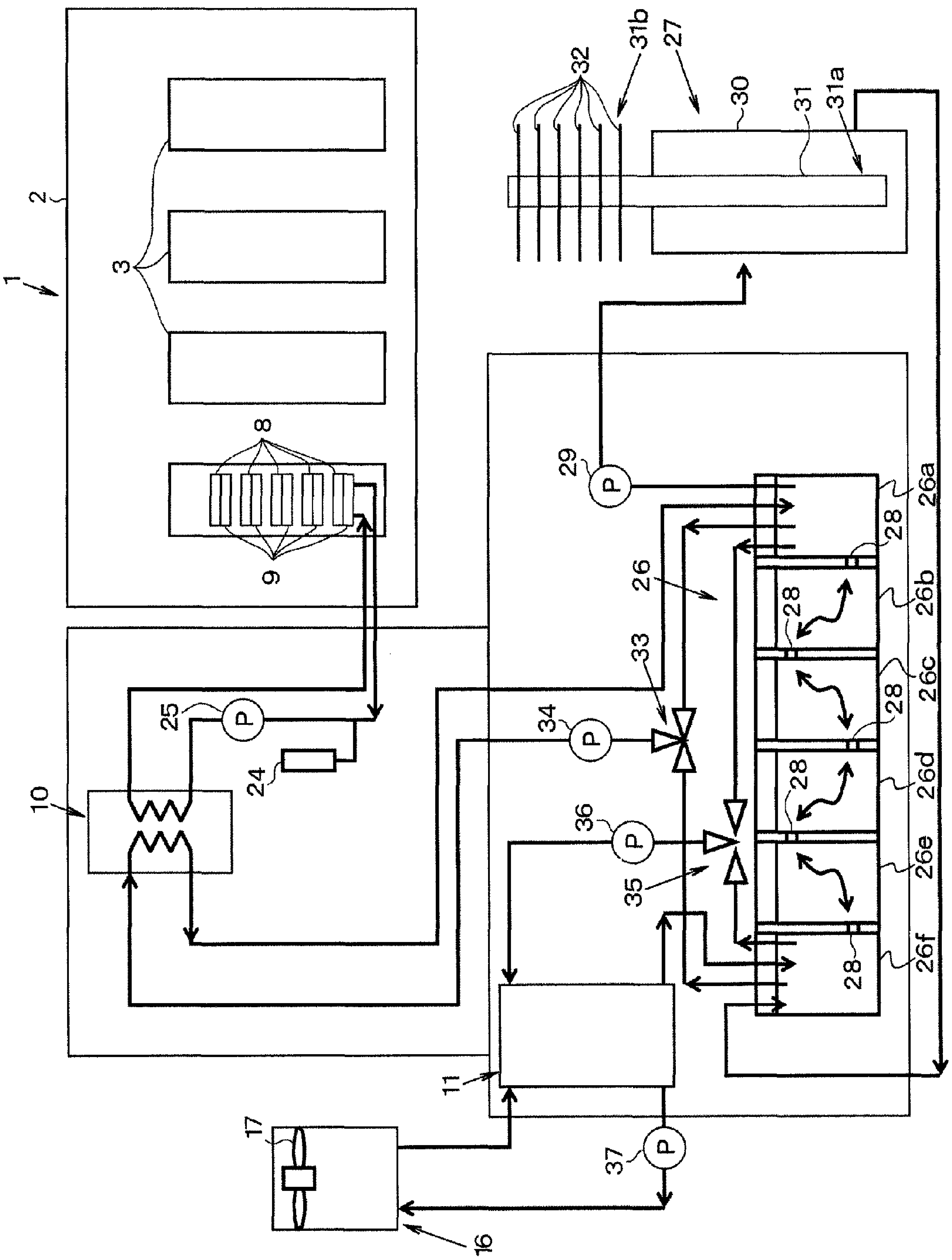
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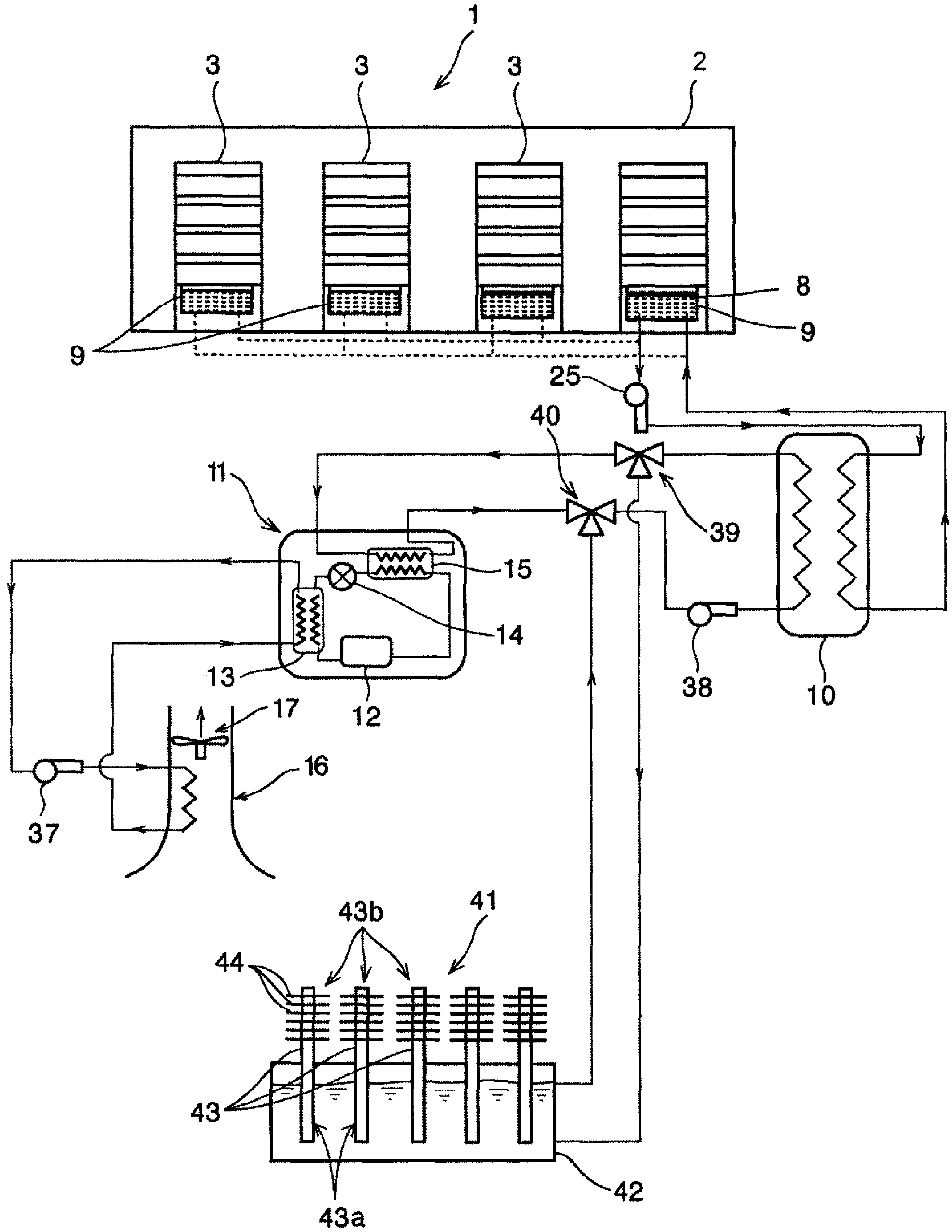
Fig. 2

Fig. 3



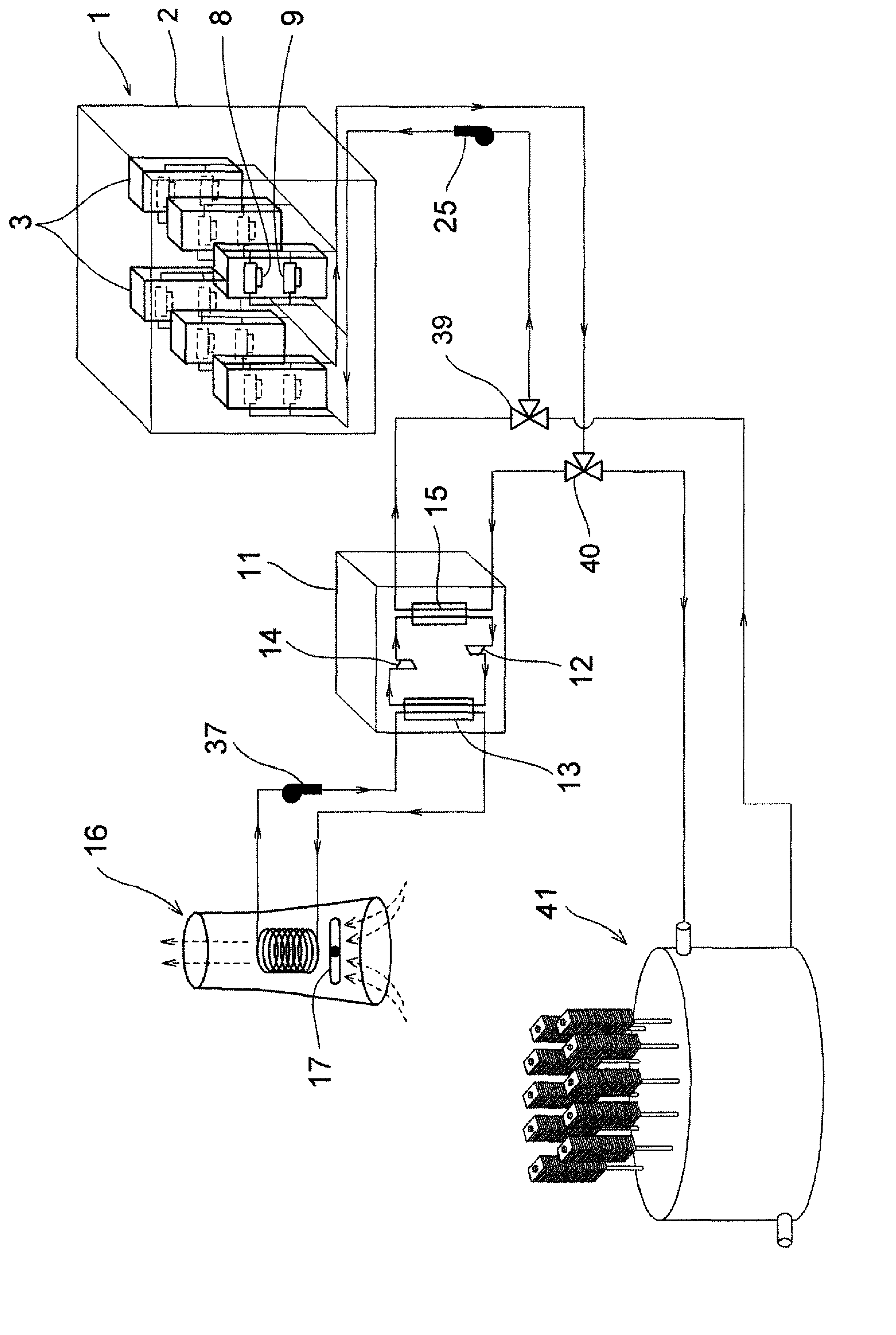


Fig. 4

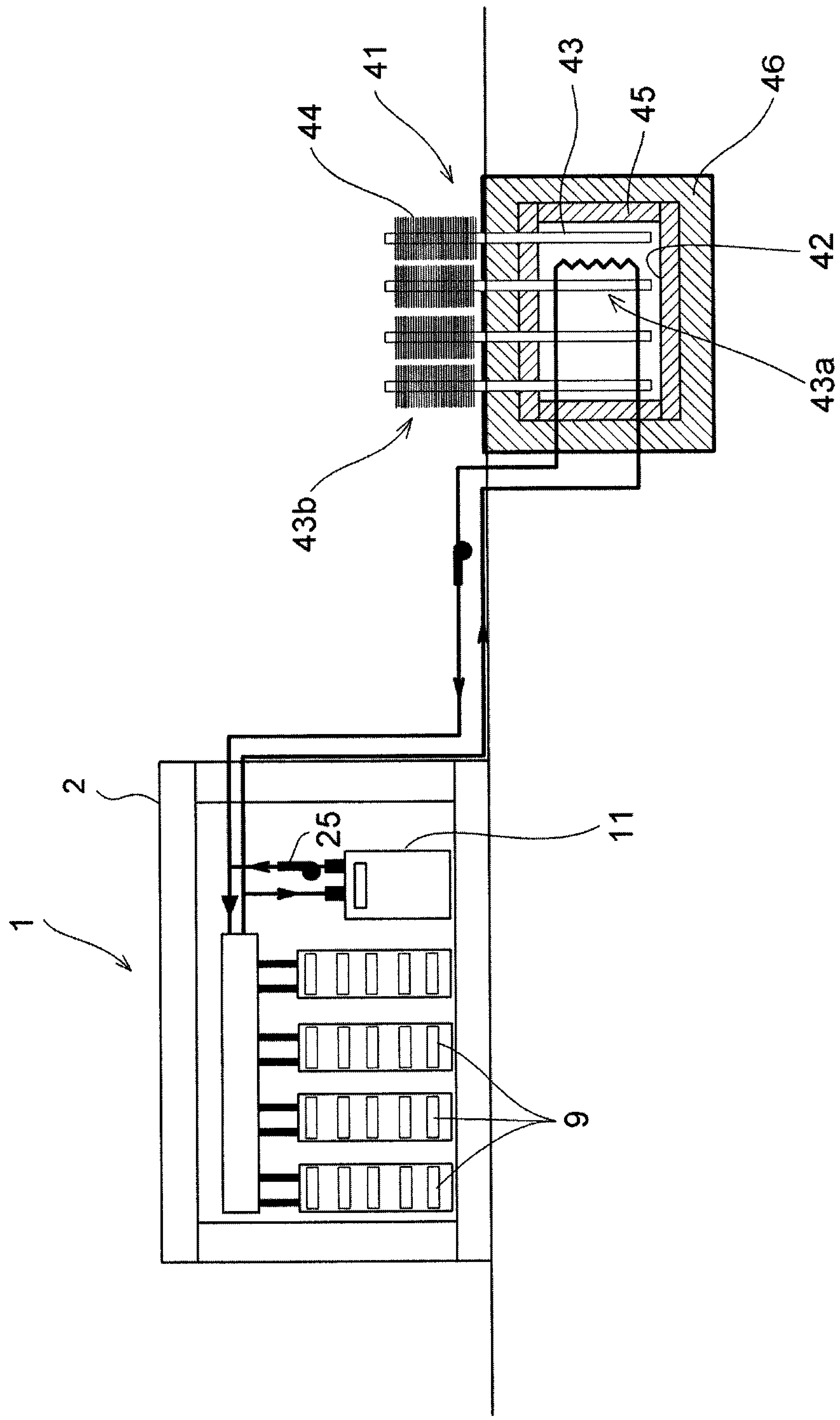


Fig. 5

Fig. 6

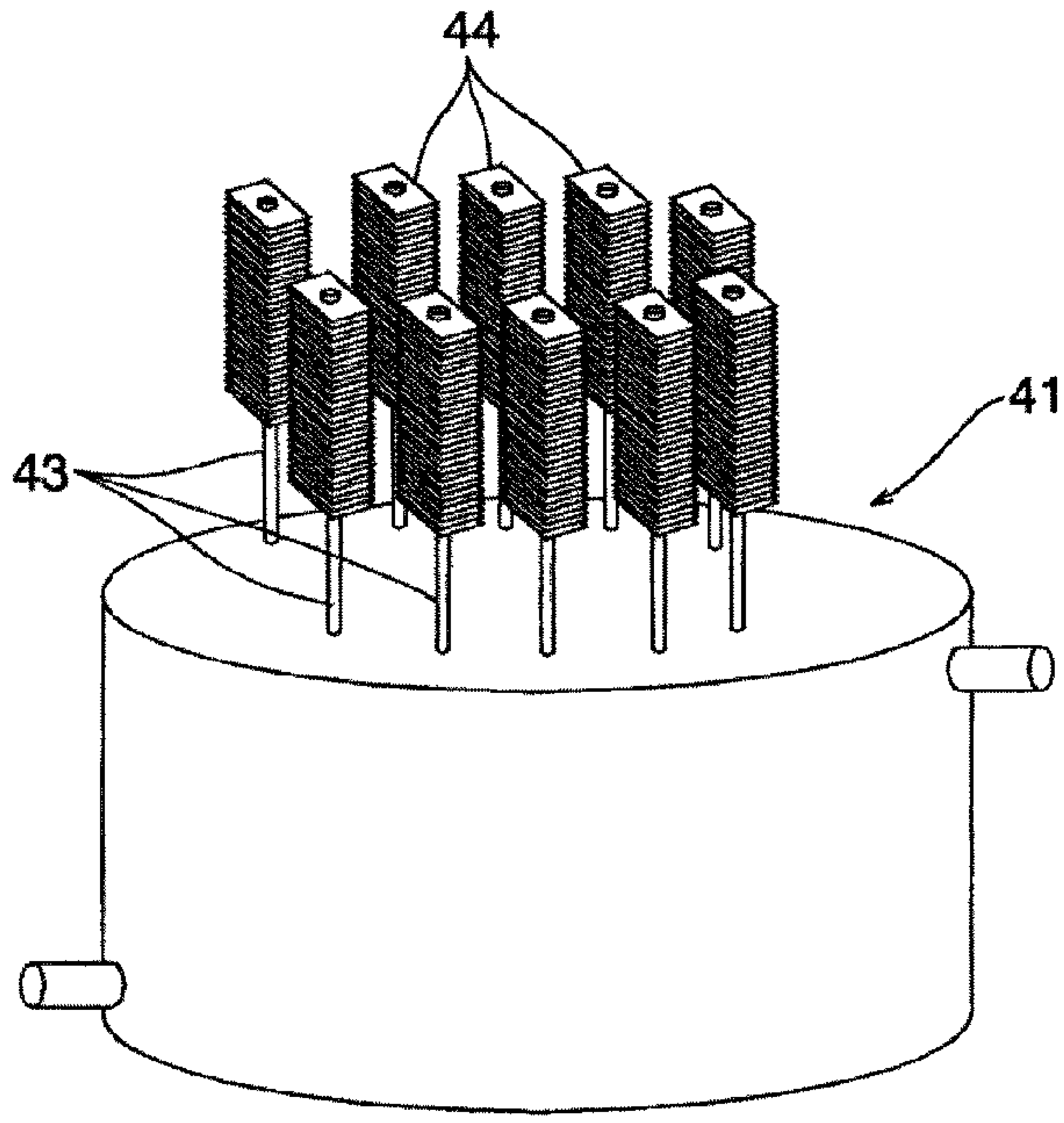


Fig. 7

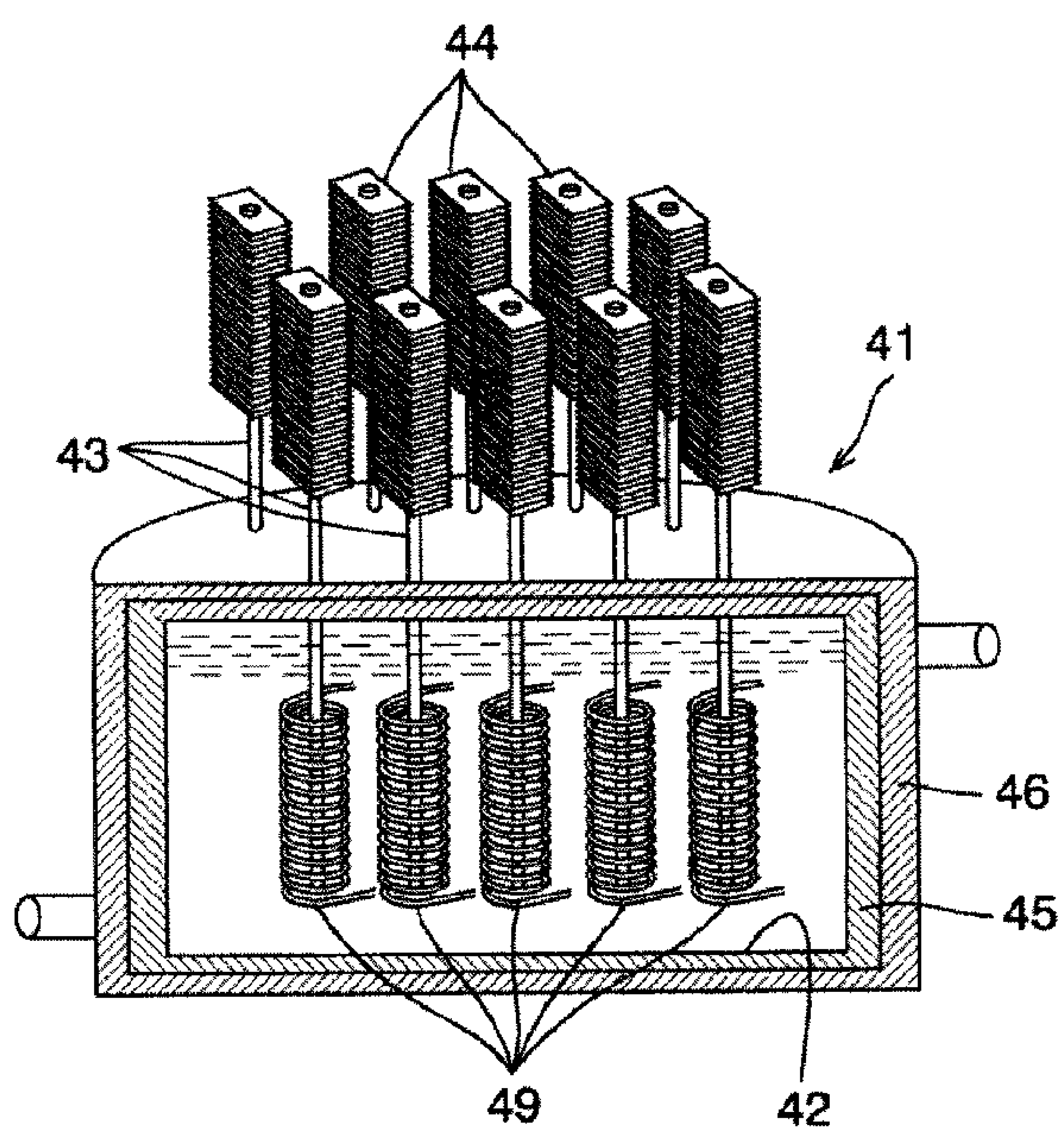


Fig. 8

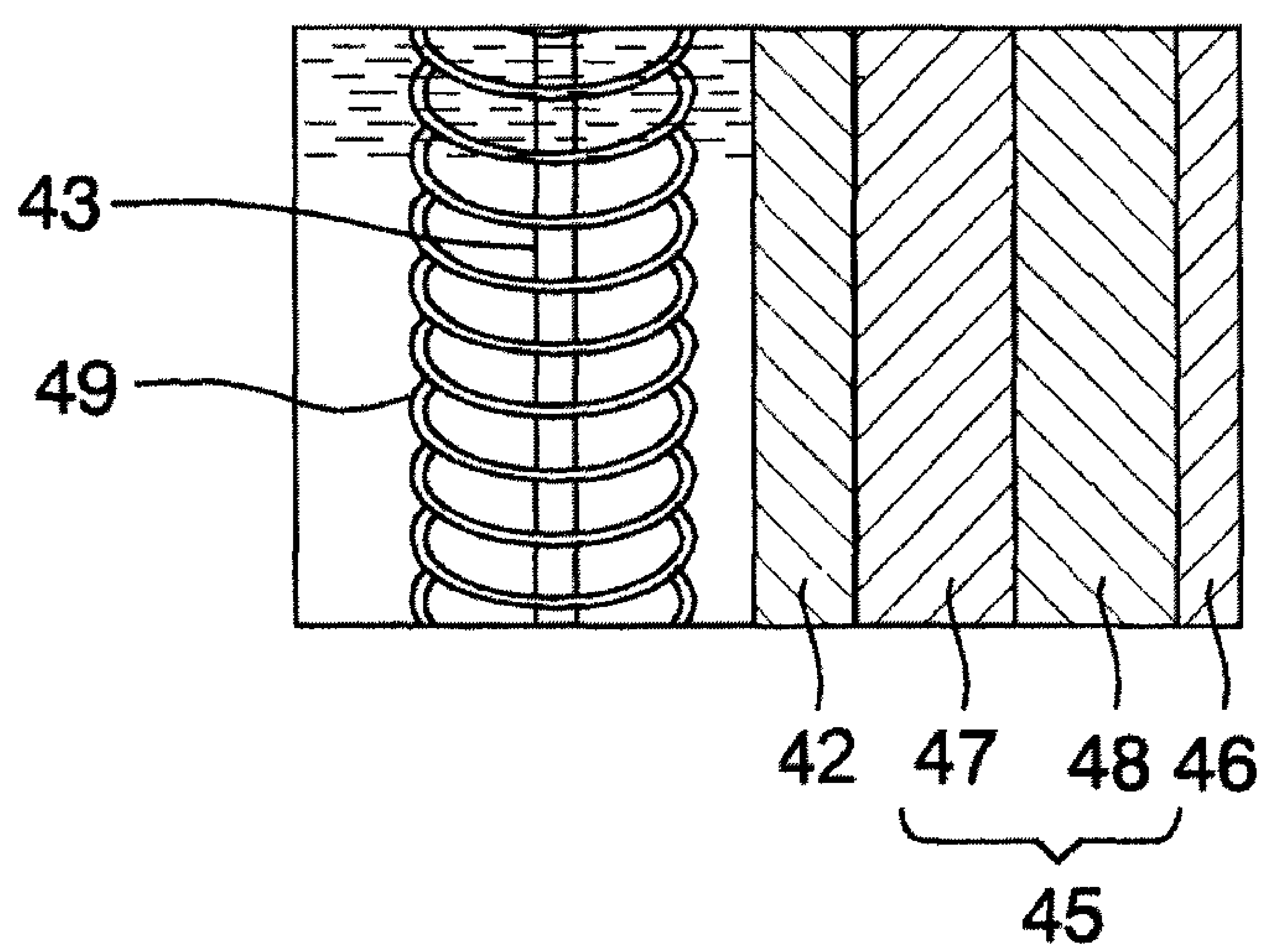


Fig. 9

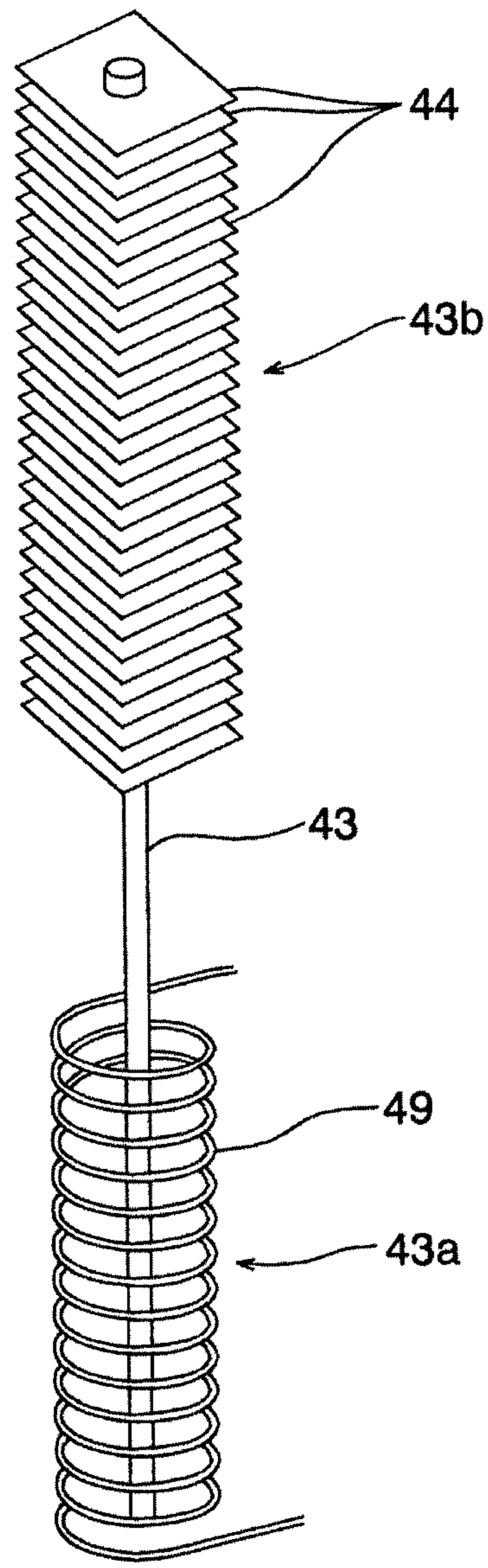
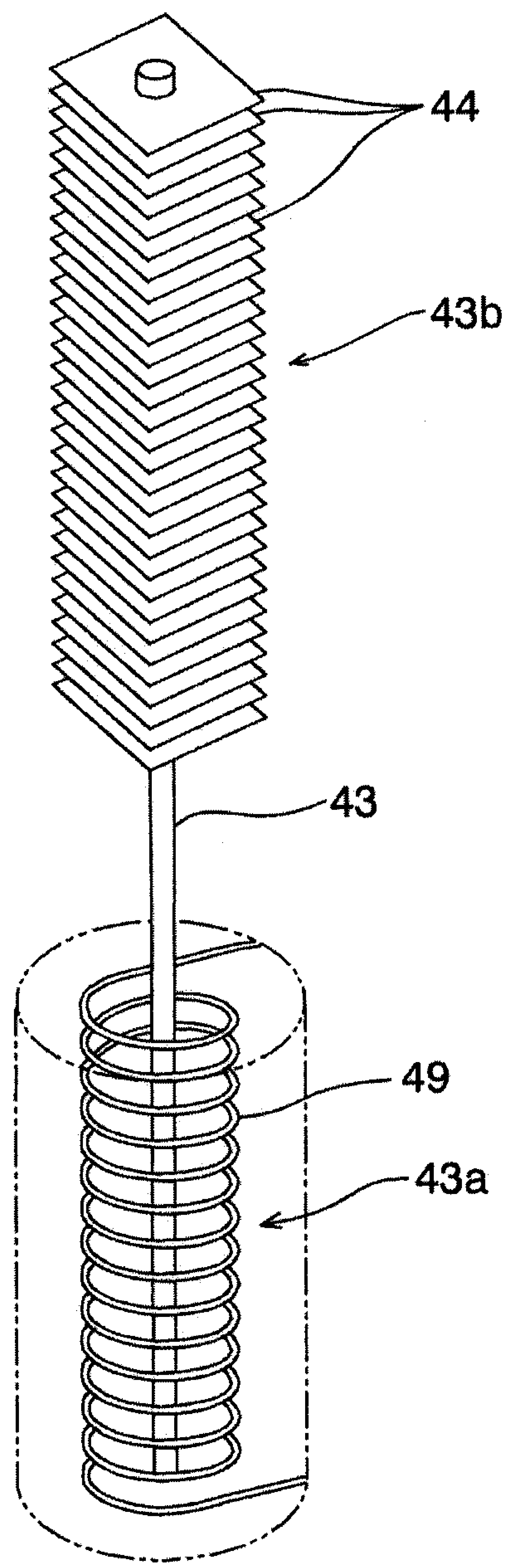


Fig. 10



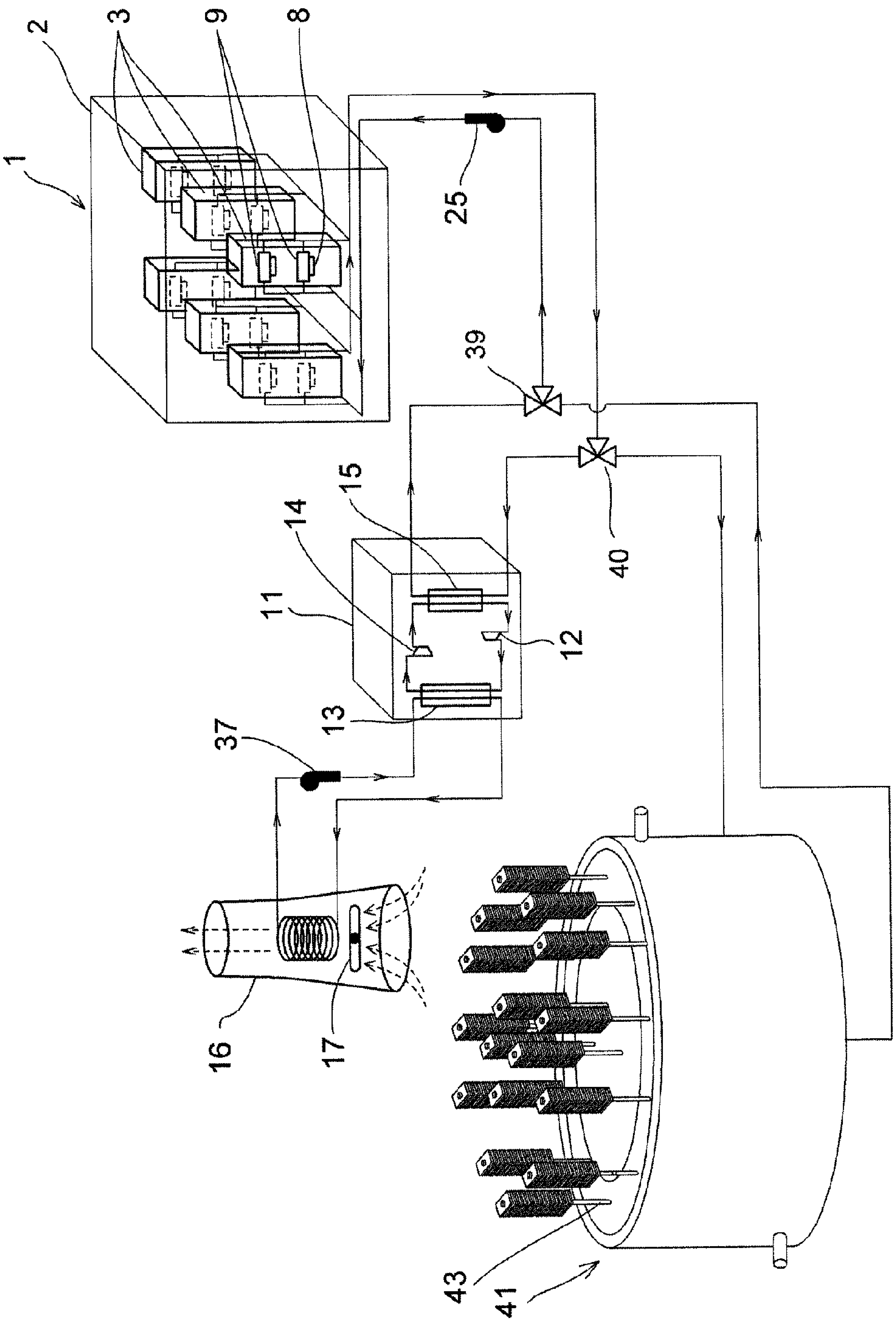


Fig. 11

Fig. 12

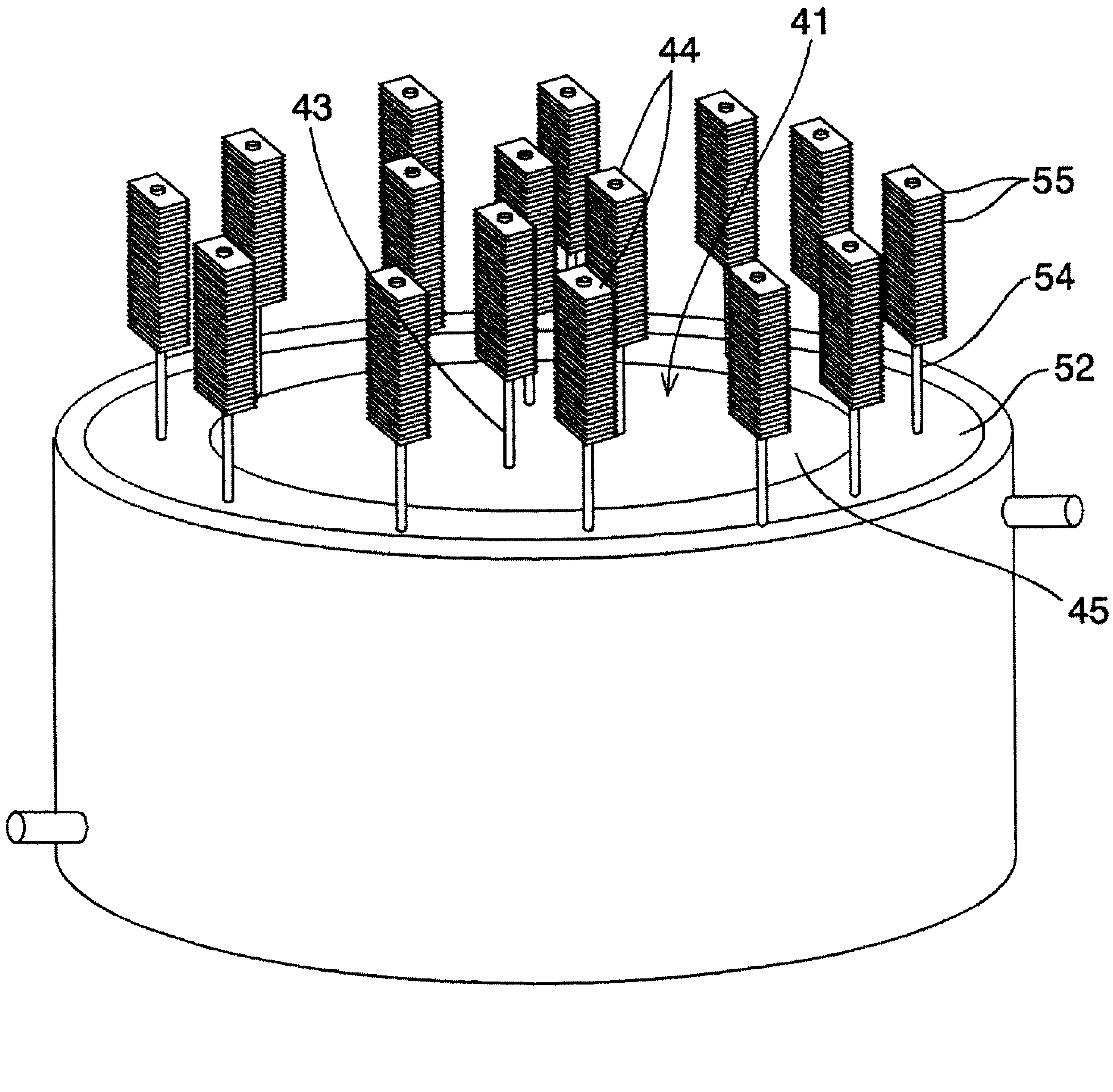


Fig. 13

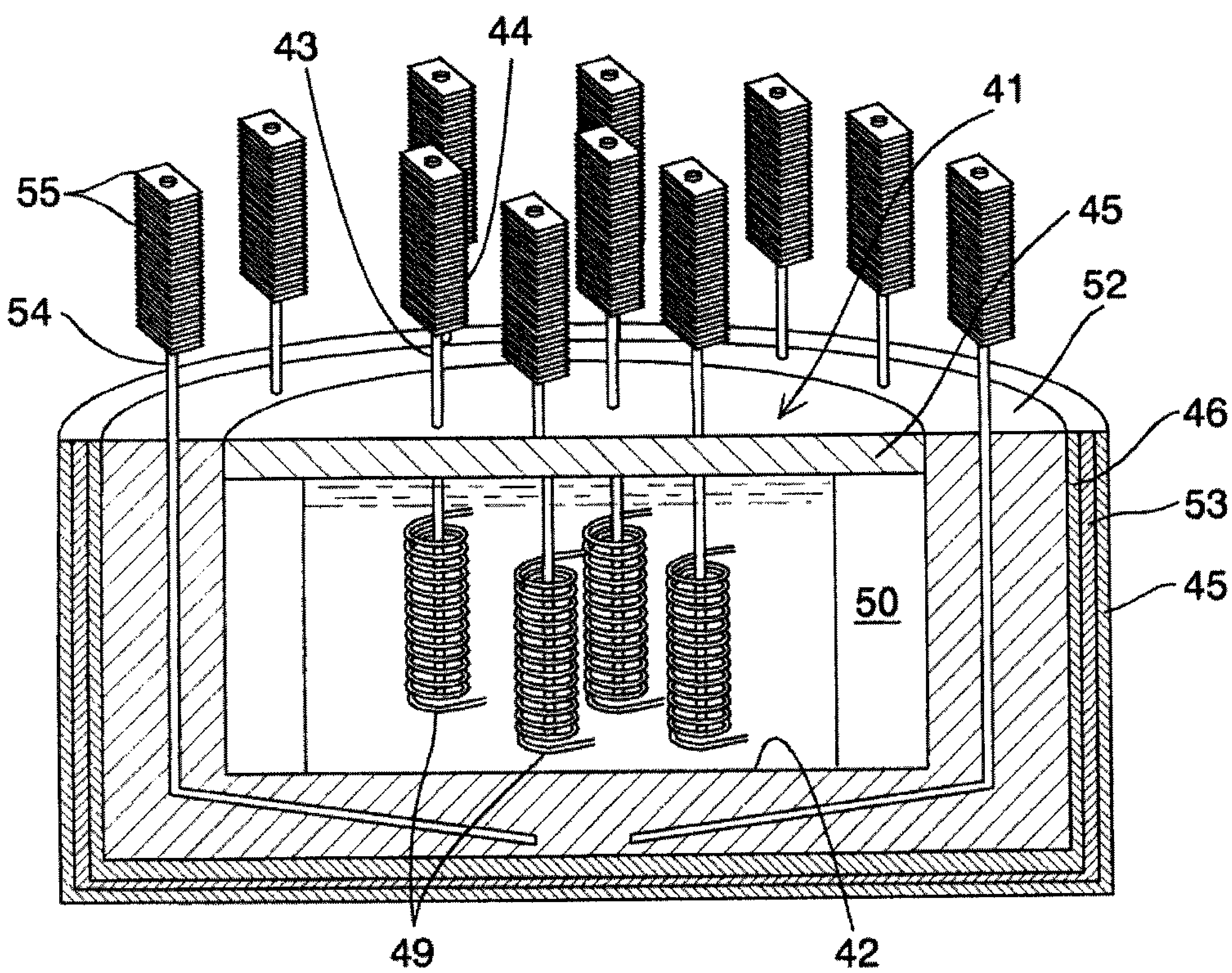


Fig. 14

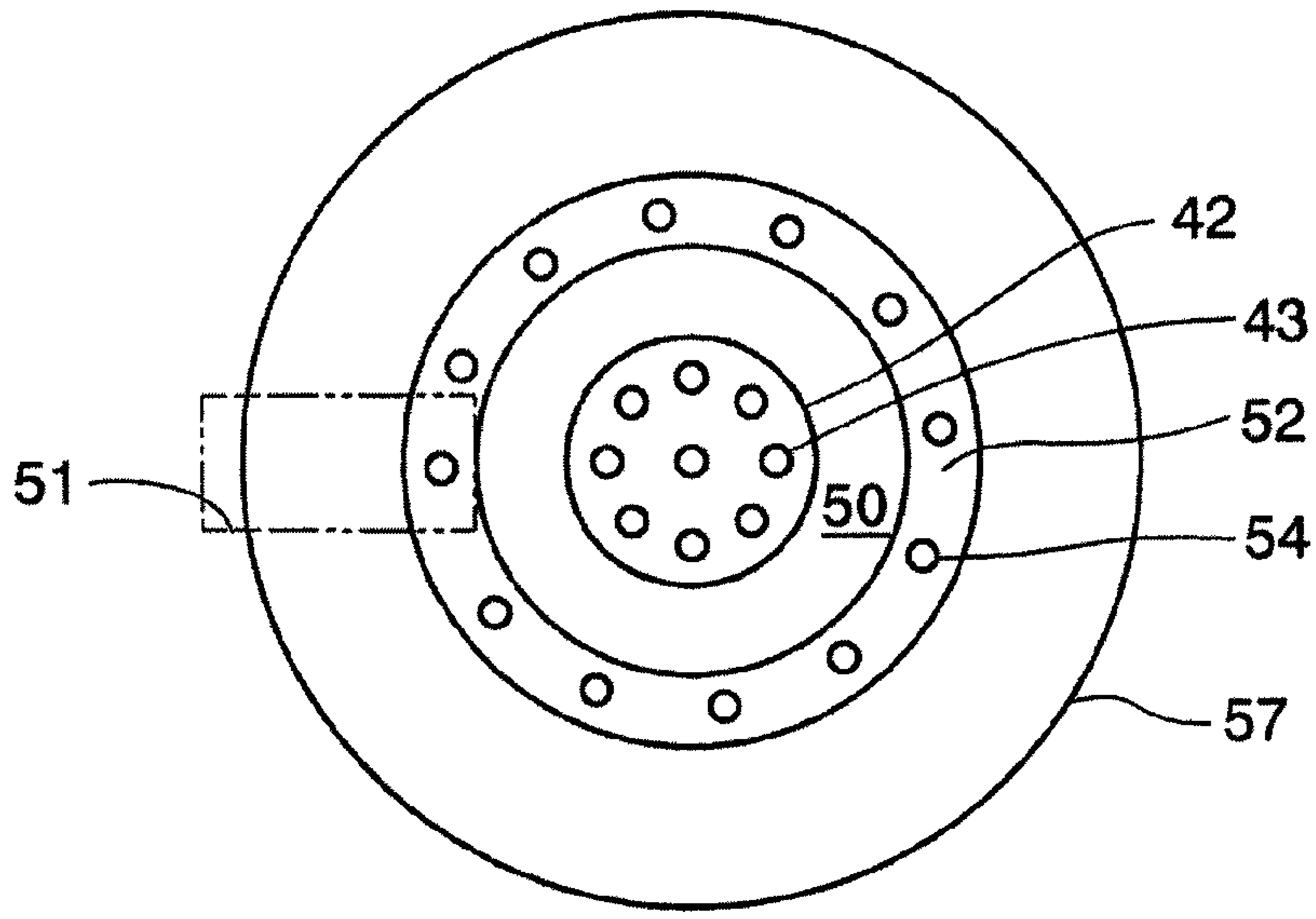


Fig. 15

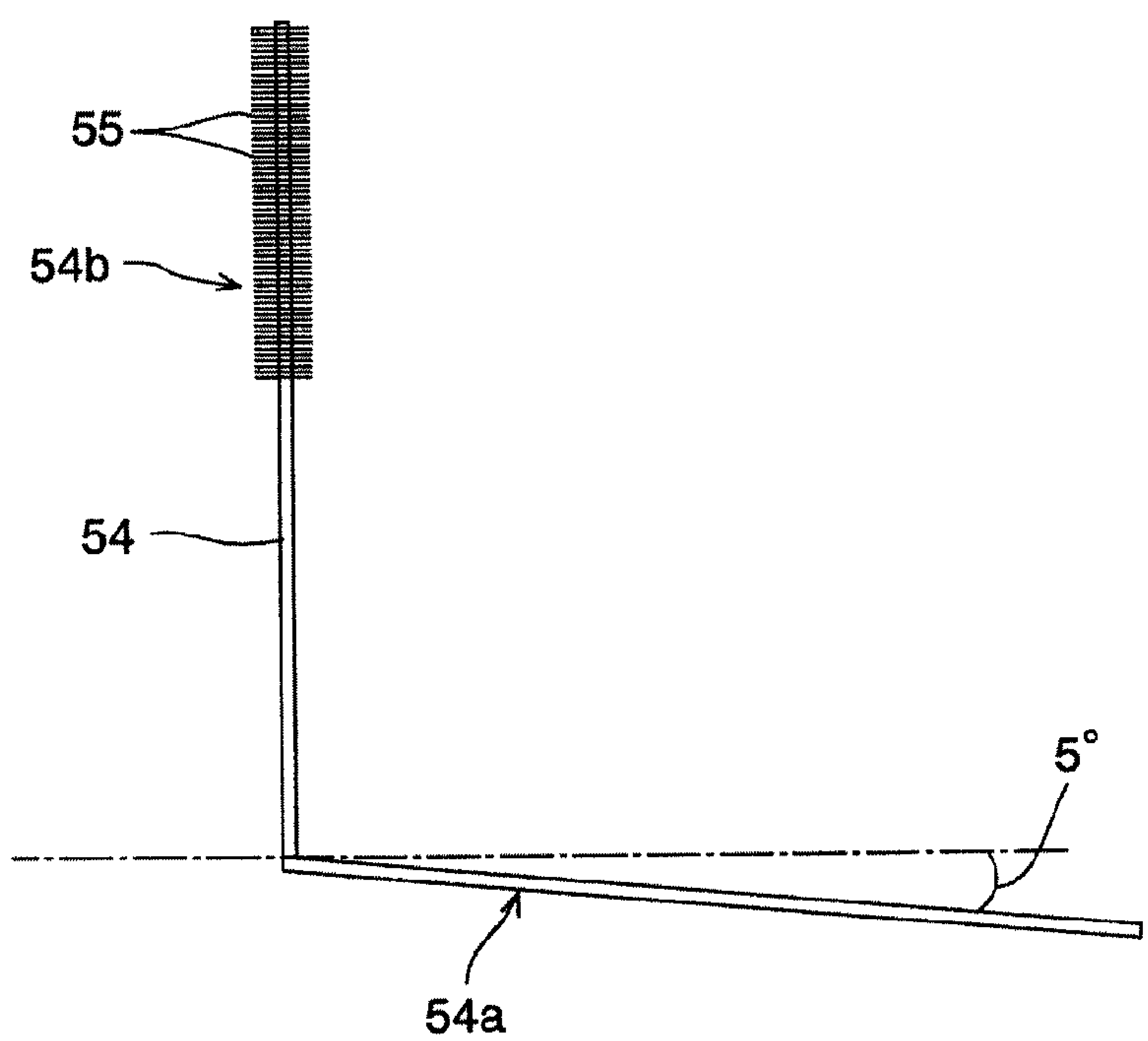


Fig. 16

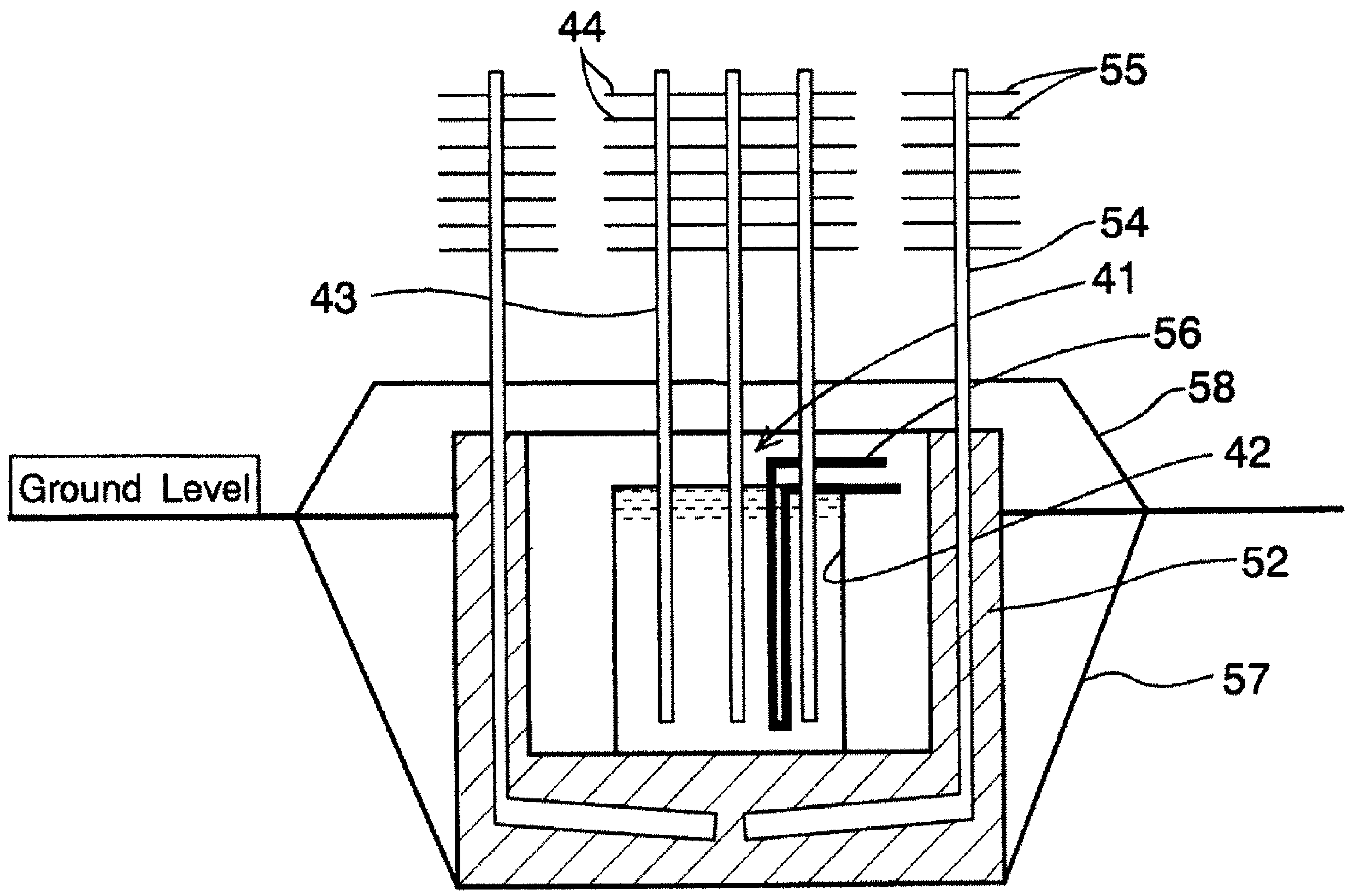
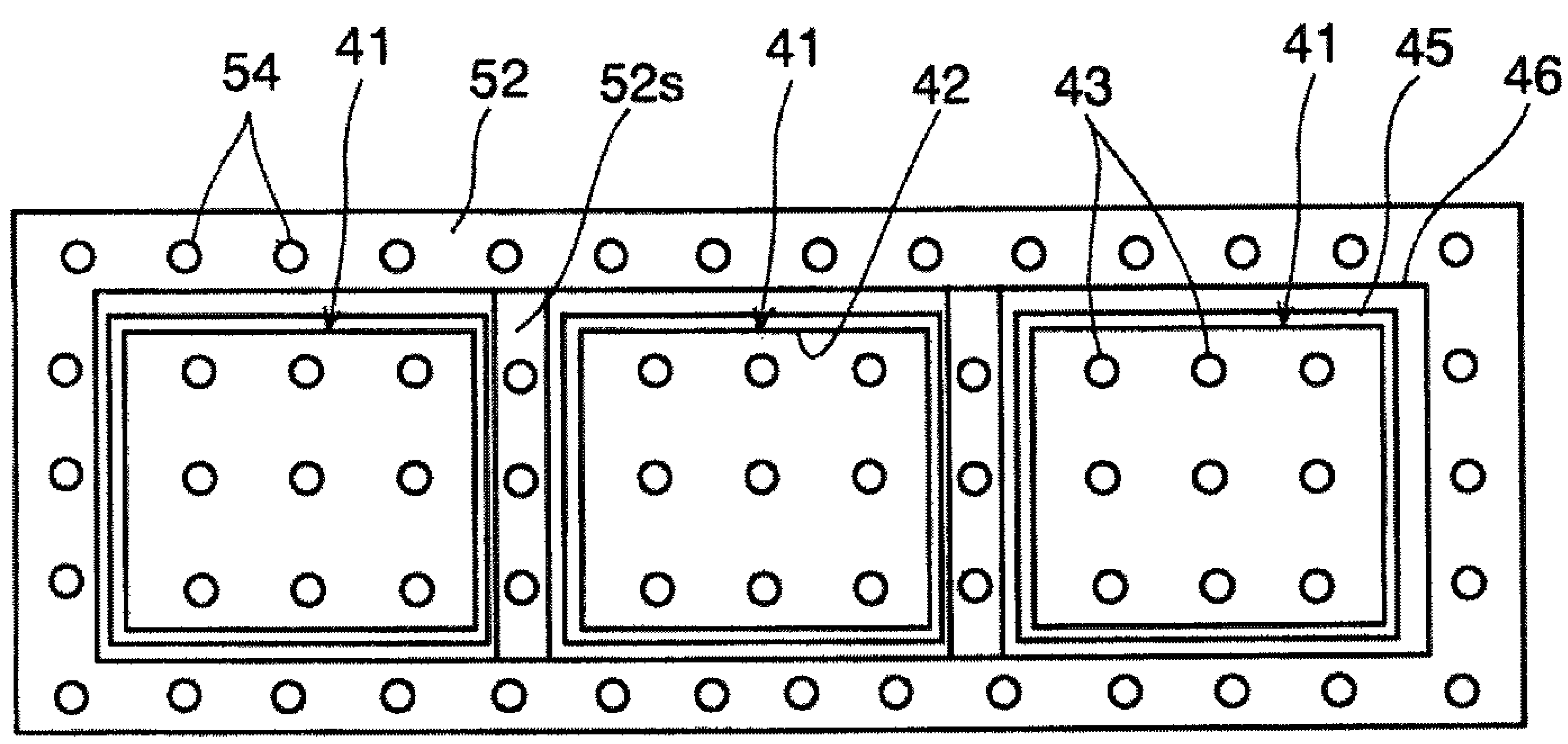


Fig. 17



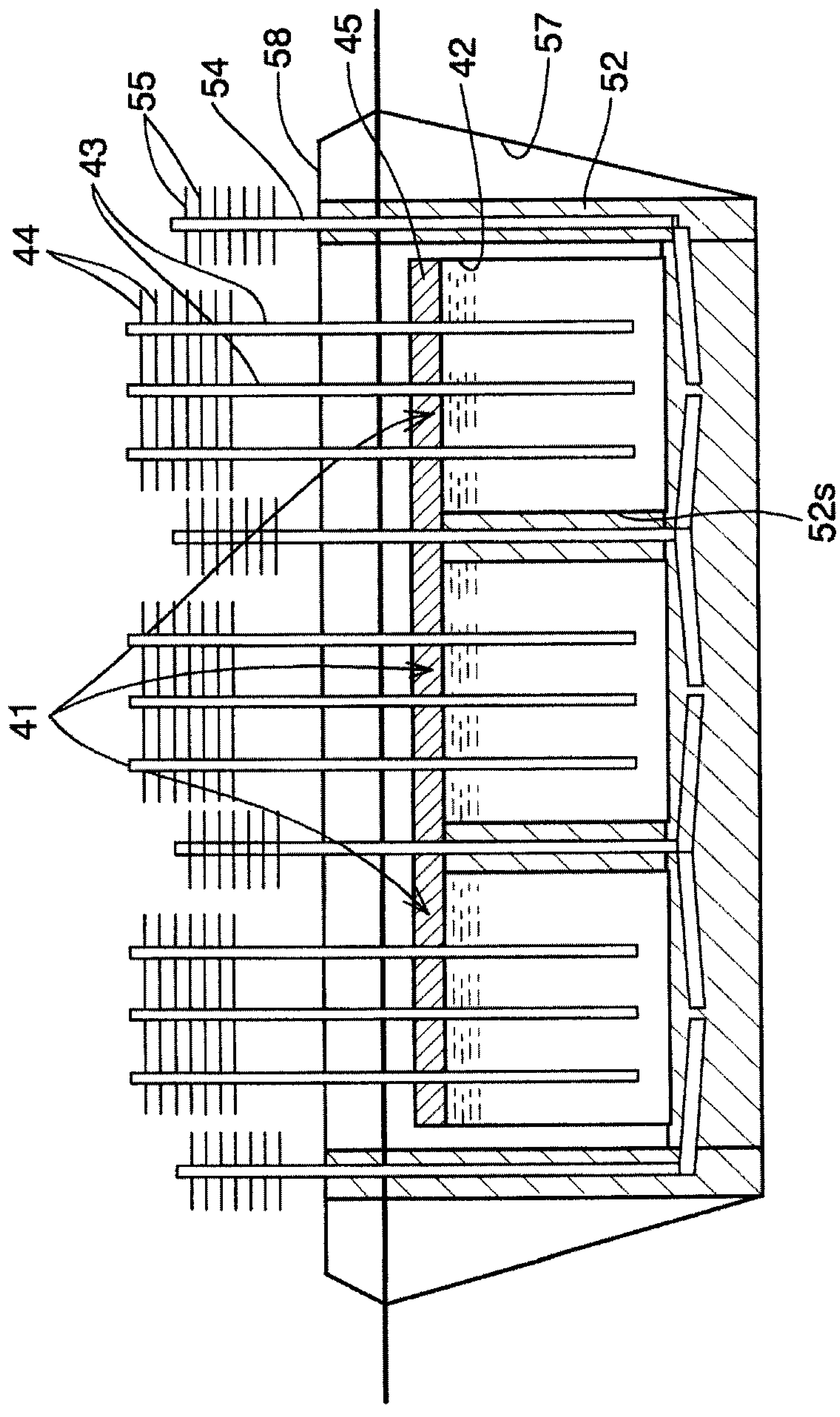
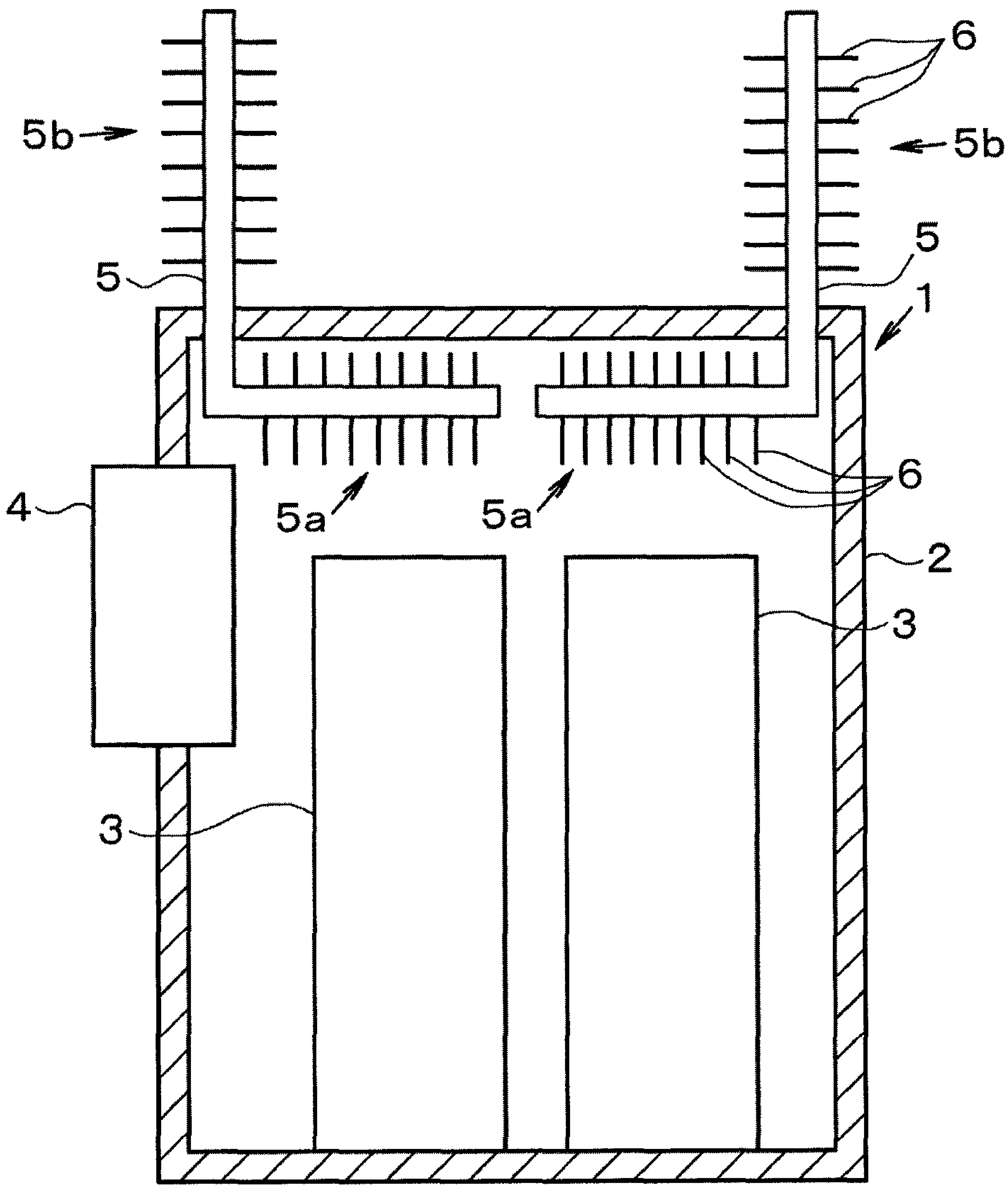


Fig. 18

Fig. 19



COOLING DEVICE, COOLING SYSTEM, AND AUXILIARY COOLING DEVICE FOR DATACENTER

The present invention claims the benefit of Japanese Patent Applications No. 2010-91680 filed on Apr. 12, 2010, No. 2010-94108 filed on Apr. 15, 2010, No. 2010-99071 filed on Apr. 22, 2010, No. 2010-121954 filed on May 27, 2010, No. 2011-41903 filed on Feb. 28, 2011 and No. 2011-41904 filed on Feb. 28, 2011 with the Japanese Patent Office, the disclosures of which are incorporated herein by reference in their entirety.

BACKGROUND

1. Field of the Invention

The present invention relates to a cooling device and a cooling system for cooling a data center comprising a plurality of computer servers, and in addition, to an auxiliary cooling device for cooling the data center in case a main cooling device cannot be used to cool the data center.

2. Discussion of the Related Art

A computer server comprises a plurality of exothermic electronic components arranged on a printed-circuit board, and those electronic components produce heat as a result of being energized to carry out data processing. Therefore, a temperature in a datacenter in which a plurality of servers is installed is raised by the heat of the electronic components. The temperature in the datacenter thus raised is conventionally lowered using an air conditioner thereby cooling the heated electronic components of the servers. In addition, the electronic components itself are cooled directly or indirectly by a refrigerant such as water, brine, etc. cooled by a chiller unit. However, since the data processing of the electronic components is carried out ceaselessly, the chiller unit has to be operated ceaselessly too. Therefore, electric consumption of the air conditioner, and a load on the chiller unit for cooling the refrigerant are increased according to an increase in an amount of the heat generated by the electronic components. As a result, a running cost of the data center increases. In order to avoid such an increase in the running cost of the data center, it is necessary to downsize the cooling system of the data center.

In addition, a backup cooling system composed mainly of a chiller unit is used in the prior art for the purpose of cooling the data center in case the air conditioner or a main chiller unit is out of order, or in case of a power outage. The backup cooling system of this kind is configured to prepare cool water by the chiller unit, and the prepared cool water is reserved in the backup cooling system to be used for cooling the data center in case of aforementioned emergency situation. Specifically, the cool water of 5 to 8 degrees is reserved in the backup cooling system in an amount sufficient to cool the data center for about six hours. Thus, the conventional backup cooling system has to be large enough to continuously contain such a large amount of water. In addition to the above-explained disadvantage, a large electricity cost is required to operate the chiller unit continuously. Therefore, it is necessary to downsize the conventional backup cooling system, and reduce the cost of running the system.

For example, an energy-saving cold storage comprising an ice making pit arranged underneath the storage is disclosed in Japanese Patent Laid-Open No. 60-207877. According to the teachings of Japanese Patent Laid-Open No. 60-207877, the ice making pit is configured to freeze water reserved therein in winter time by dissipating heat of the water to the atmosphere using a heat pipe penetrating through the storage. Therefore, an inner space of the storage can be cooled by cold energy of the ice without running cost.

Japanese Patent Laid-Open No. 2002-372354 discloses a cooling system capable of saving on power consumption and cost. According to the teachings of Japanese Patent Laid-Open No. 2002-372354, a refrigerator is driven during nighttime thereby storing ice in a storage tank utilizing cheaper nighttime electricity. The cold energy of the ice thus prepared during the nighttime is utilized during the daytime by circulating cold water melted from the ice within a cold water showcase. Further, a coil is arranged around the cold water showcase and refrigerant is circulated through the coil. Therefore, the cold water showcase serves as an evaporator for the refrigerator.

In addition, Japan Patent Laid-Open No. 11-223449 discloses a cooling system comprising: a chiller unit for cooling brine to prepare ice: a heat exchanger for exchanging heat between the cooling system and the chiller unit; and an ice storage tank. According to the teachings of Japanese Patent Laid-Open No. 11-223449, the cooling system is connected with both of the heat exchanger and the chiller unit. The ice in the storage tank can be used to keep the cooling system at a low temperature in the form of cool water. Therefore, the cooling system taught by Japanese Patent Laid-Open No. 11-223449 can be kept at a low temperature not only by the chiller unit but also by the cold energy of the ice. In addition, it is also possible to cool down the cooling system using both of the chiller unit and the ice in the storage tank. According to the teachings of Japanese Patent Laid-Open No. 11-223449, the chiller unit is also operated to prepare the ice during the nighttime utilizing cheaper nighttime electricity.

Further, Japanese Patent Laid-Open No. 7-4800 discloses a heat pipe type supercooling ice making equipment comprising: a heat pipe; a jacket for circulating refrigerant from a refrigerator arranged on an upper part of the heat pipe; a heater arranged on a lower part of the heat pipe; a coil-shaped resin tube for letting water therethrough which is wound around the heat pipe; an ice heat storage device (i.e., a tank); and a supercooled water destructing plate to which the water discharged from the tube is dropped. According to the teachings of Japanese Patent Laid-Open No. 7-4800, the water is circulated between the tube and the ice heat storage device while driving the refrigerator using nighttime electricity. Consequently, the heat pipe is activated as a heat exchanger, and the water flowing through the tube is supercooled. The water thus supercooled is discharged from the tube and collide against the supercooled water destructing plate and is frozen.

However, according to the cold storage taught by Japanese Patent Laid-Open No. 60-207877, cold energy of the ice in the ice making pit may be radiated to the atmosphere through the soil around the ice making pit when the external temperature is higher than a coagulation temperature.

Meanwhile, according to the teachings of Japanese Patent Laid-Open No. 2002-372354 and No. 11-223449, the chiller unit is the only cooling means storing the cold energy. Therefore, in case the chiller unit has some kind of trouble or in case of power outage, the cooling systems taught by Japanese Patent Laid-Open No. 2002-372354 and No. 11-223449 are unable to perform their cooling function.

Also, the ice making equipment taught by Japanese Patent Laid-Open No. 7-4800 cannot make ice in case the refrigerator is in trouble or in case of power outage. In addition to the above-explained disadvantage, according to the teachings of Japanese Patent Laid-Open No. 7-4800, the cold energy in the ice heat storage device cannot be transported in case the water therein is completely frozen.

SUMMARY

The present invention has been conceived noting above-mentioned problems, and it is therefore an object of the present invention to provide a cooling system for cooling a data center which is capable of reducing a running cost for cooling an exothermic electronic component of a computer server. In addition, another object of the present invention is to provide an auxiliary cooling device for cooling the exothermic electronic component in case the cooling device is not available to cool the exothermic electronic component.

In order to achieve the aforementioned objective, according to a first example of the present invention, there is provided a cooling system for a data center, in which a plurality of servers having exothermic electronic components is installed in a housing, comprising: a circuit, in which a cooling medium is circulated therethrough; a main cooling device, which is connected with the electronic components through the circuit, and to which the cooling medium heated by drawing heat from the electronic components is returned; and an auxiliary cooling device, which is arranged on a return pipe of the circuit between the main cooling device and the electronic components to assist the main cooling device in cooling the cooling medium.

The auxiliary cooling device comprises a tank which stores the cooling medium therein, and a plurality of heat pipes which is adapted to cool or freeze the cooling medium by radiating heat of the cooling medium to the atmosphere. For example, the heat pipe is a thermosiphon, in which a volatile and condensable working fluid is encapsulated air-tightly, and a direction to transport the heat is restricted unilaterally by allowing condensed working fluid to drop only gravitationally. Specifically, one of end portions of the thermosiphon is immersed into the cooling medium in the tank to serve as an evaporating portion, and other end portion of the thermosiphon is exposed to the atmosphere to serve as a condensing portion.

The cooling system according to the first example further comprises a heat exchanger, which is arranged on the circuit between the electronic components and the cooling devices to exchange the heat of the electronic components and cold energy of the cooling medium.

The cooling system further comprises a cooling tower, which is connected with the main cooling device to radiate heat of the main cooling device to the atmosphere.

In addition, the auxiliary cooling device further comprises a flow channel letting through the cooling medium supplied to the tank unilaterally.

According to the second example of the present invention, the cooling system further comprises a mixing tank, to which the cooling medium heated by the electronic component, and the cooling medium cooled by the main cooling device or the auxiliary cooling device, are supplied to regulate the temperature thereof. The cooling medium mixed in the mixing tank is selectively supplied to the main cooling device and the auxiliary cooling device to be cooled, and also used to cool the electronic component.

The mixing tank is divided into a plurality of mixing chambers, and the adjoining mixing chambers are connected by a through hole. Specifically, the cooling medium heated by the electronic component is supplied to one of the mixing chambers connected with the electronic component, and the cooling medium cooled by the main cooling device or the auxiliary cooling device is supplied to another one of the mixing chambers connected with the main cooling device and the auxiliary cooling device. Therefore, the cooling medium heated by the electronic component, and the cooling medium cooled by the main cooling device or the auxiliary cooling device are mixed gradually in the mixing tank while flowing across the mixing chambers.

According to the second example, the cooling system further comprises, a first switching valve, which switches a route for feeding the cooling medium from the mixing tank to the electronic component between a route from said one of the mixing chamber to the electronic component, and a route from said another one of the mixing chamber to the electronic component; a first pump, which is arranged between the first switching valve and the electronic component to feed the cooling medium to the electronic component; a second switching valve, which switches a route for feeding the cooling medium from the mixing tank to the main cooling device between a route from said one of the mixing chamber to the main cooling device, and a route from said another one of the mixing chamber to the main cooling device; a second pump, which is arranged between the second switching valve and the main cooling device to feed the cooling medium to the main cooling device; and a third pump, which is arranged on a route between said one of the mixing chamber and the auxiliary cooling device to feed the cooling medium in said one of the mixing chamber to the auxiliary cooling device.

According to the third example of the present invention, the cooling system of the first example further comprises: a first switching valve, which returns the cooling medium heated by the heat from the electronic components selectively to the main cooling device and the auxiliary cooling device; and a second switching valve, which supplies the cooling medium to the electronic component selectively from the main cooling device and the auxiliary cooling device.

The cooling system according to the third example further comprises: a first pump, which is arranged on the circuit connecting the electronic component and the heat exchanger to circulate the cooling medium therethrough; a second pump, which is arranged on the circuit connecting the heat exchanger and the main cooling device to circulate the cooling medium therethrough; and a third pump, which is arranged on the circuit connecting the main cooling device and the cooling tower to circulate the cooling medium therethrough.

According to the fourth example, the auxiliary cooling device further comprises a heat insulating layer, which covers the tank to prevent the tank from being warmed by an external heat.

In addition, according to the fourth example, the auxiliary cooling device further comprises: a cold storage medium, which is sealed in the tank to be frozen by external cold energy entering into the tank through the thermosiphon; and a heat exchanging tube, which is arranged around the evaporating portion of the thermosiphon, and through which the cold energy of the frozen cold storage medium in the tank is transferred to the cooling medium flowing therethrough.

Specifically, the heat insulating layer comprises: an inner layer formed of an evacuated panel in which an internal pressure is reduced to be lower than an atmospheric pressure; and an outer layer formed of heat insulating porous material.

The aforementioned heat exchanging tube includes a coil heat exchanger formed by winding a hollow tube around the evaporating portion of the thermosiphon; and material of the heat exchanging tube is selected from the group consisting of copper, copper alloy, aluminum, aluminum alloy, and synthetic resin.

According to a fifth example of the present invention, the auxiliary cooling device further comprises: a soil layer containing predetermined moisture and covering the tank; and another heat pipe which is buried in the soil layer at least partially to freeze the moisture in the soil layer by radiating the heat of the moisture unilaterally to the atmosphere, under the condition in which a temperature of the moisture in the soil layer is higher than an external temperature and the external temperature is lower than a predetermined temperature.

The aforementioned another heat pipe is also a thermosiphon, in which a volatile and condensable working fluid is encapsulated air-tightly, and a direction to transport the heat is restricted unilaterally by allowing the condensed working fluid to drop only gravitationally. Specifically, one of end portions of the thermosiphon buried in the soil layer serves as an evaporating portion; and other end portion of the thermosiphon exposed to the atmosphere serves as a condensing portion.

Specifically, a thickness of the soil layer is approximately 1 meter, and material of the soil layer is selected from a group consisting of sand, loam and clay. For example, in case the soil layer is formed of sand, a moisture content of the soil layer is kept within a range of 2.5 to 10%, in case the soil layer is formed of loam, a moisture content of the soil layer is kept within a range of 10 to 17.5%, and in case the soil layer is formed of clay, a moisture content of the soil layer is kept within a range of 17.5 to 25%.

In addition, the heat exchanging tube includes a U-shaped heat exchanger formed by bending a hollow tube into U-shape and arranged in the vicinity of the evaporating portion of the thermosiphon.

According to the sixth example of the present invention, the cooling system further comprises: an air conditioner, which is arranged in the housing to control the temperature in the housing thereby cooling the server; and an assist heat pipe, which transports heat in the housing unilaterally to the atmosphere thereby assisting the air conditioner. The assist heat pipe is also a thermosiphon, in which a volatile and condensable working fluid is encapsulated air-tightly, and in which a direction to transport the heat is restricted unilaterally by allowing the condensed working fluid to drop only gravitationally. Specifically, one of end portions of the thermosiphon is situated in the housing above the server in a direction of gravitational force, and the other end portion of the thermosiphon is exposed to the atmosphere.

In addition, the auxiliary cooling device is buried in the ground in a cold region where a freezing index is higher than 400 degree C.·day.

Thus, according to the cooling device of the first example, the auxiliary cooling device is arranged on the pipeline returning the cooling medium from the electronic component to the main cooling device. Therefore, the cooling medium heated as a result of cooling the electronic components is cooled prior to reaching the main cooling device. The cooling medium thus cooled by the auxiliary cooling device is then supplied to the main cooling device. As a result, a burden of the main cooling device can be lightened so that the main cooling device can be downsized and the running cost thereof can be reduced. In case the temperature of the cooling medium circulating in the circuit is lowered to a desired temperature, the main cooling device can be stopped. In addition to the above-explained advantages, since the auxiliary cooling device is configured to radiate the heat of the cooling medium using the heat pipe, maintenance and repair of the auxiliary cooling device is substantially unnecessary.

In the auxiliary cooling device, the heat of the cooling medium in the tank is radiated to the atmosphere through the heat pipe. As described, the thermosiphon is used as the heat pipe, and the direction of the thermosiphon to transport the heat is restricted to one direction by thermal diode characteristics thereof. Therefore, an external heat cannot enter into the auxiliary cooling device through the thermosiphon, that is, the cooling medium will not be warmed by the external heat.

As described, the cooling system of the present invention comprises the heat exchanger between the server and the cooling devices. Therefore, the heat of the electronic component and the cold energy of the main cooling device can be exchanged in the heat exchanger so that the cooling medium heated by the electronic component can be cooled prior to reaching the auxiliary cooling device.

Since the main cooling device is connected with the cooling tower, the heat of the cooling medium returned to the main cooling device can be radiated to the atmosphere from the cooling tower.

As described, according to the second example, the flow channel for letting through the cooling medium unilaterally is formed in the auxiliary cooling device. Therefore, the cooling medium can be cooled by the thermosiphon when flowing through the auxiliary cooling device.

According to the second example of the present invention, the cooling medium heated by the electronic component, and the cooling medium cooled by the main and the auxiliary cooling devices are supplied to the mixing tank. Therefore, those cooling mediums are mixed together in the mixing tank, and as a result, the temperature of the cooling medium is first neutralized in the mixing tank. The cooling medium thus neutralized in the mixing tank can be supplied selectively to the main cooling device and the auxiliary cooling device to be cooled. For this reason, a burden on the main cooling device can be lightened and cold energy in the ice storage device can be prevented from being consumed wastefully. Moreover, in case the cooling medium can be cooled sufficiently in the mixing tank, the cooling medium can also be supplied to the electronic component directly from the mixing chamber. In this case, the electronic components can be cooled by the cooling medium cooled only in the mixing tank without running the main cooling device.

As described, the mixing tank is divided into a plurality of mixing chambers, and adjoining chambers are communicated through a through hole. Specifically, the cooling medium heated by the electronic component is supplied to one of the mixing chambers connected with the electronic component, and the cooling medium cooled by the main cooling device or the auxiliary cooling device is supplied to another one of the mixing chambers connected with the main cooling device and the auxiliary cooling device. The cooling medium supplied to said one of the mixing chamber is convectively migrated toward said another one of the mixing chamber through the through holes, and the cooling medium supplied to said another one of the mixing chamber is convectively migrated toward said one of the mixing chamber through the through holes. Therefore, the cooling medium of high temperature and the cooling medium of low temperature can be mixed stepwise while flowing across the mixing chambers.

In addition to the above explained advantages, according to the cooling system of the second example, the cooling medium can be supplied to the electronic component selectively from said one of the mixing chamber and said another one of the mixing chambers depending on the situation by switching the first switching valve. Therefore, the electronic component can be prevented from being cooled insufficiently or excessively. Likewise, the cooling medium can be supplied to the main cooling device selectively from said one of the mixing chamber and said another one of the mixing chambers depending on the situation by switching the second switching mechanism. Therefore, a burden on the main cooling device can be lightened.

According to the cooling system of the third example, the cooling medium heated by the heat of the electronic component can be returned selectively to the main cooling device and to the auxiliary cooling device by switching the first switching mechanism, and the cooling medium cooled in the main cooling device and the auxiliary cooling device can be selectively used to cool the electronic component by switching the second switching mechanism. Therefore, the cold energy stored in the auxiliary cooling device can be used to cool the electronic component even if the main cooling device is not available.

In addition to the above-explained advantages, according to the third example, the cooling medium can be forced to circulate by the first pump in the circuit connecting the electronic component and the heat exchanger, by the second pump in the circuit connecting the heat exchanger and the main cooling device, and by the third pump in the circuit connecting the main cooling device and the cooling tower.

According to the fourth example, the tank of the auxiliary cooling device is covered by the heat insulating layer. Therefore, the cold energy stored in the auxiliary cooling device can be prevented from being wasted by the external heat around the tank so that the cold energy stored therein can be maintained over long periods.

Further, according the fourth example, the cold storage medium is sealed in the tank of the auxiliary cooling device instead of the cooling medium in a manner not to circulate in the cooling system, and in a manner to be frozen by the external cold energy entering into the tank through the thermosiphon. In addition, the heat exchanging tube is formed around the thermosiphon. Therefore, the cold energy of the frozen cold storage medium can be transferred easily to the liquid phase cooling medium flowing through the heat exchanging tube.

As described, the heat insulating layer comprises the inner layer formed of an evacuated panel in which an internal pressure is reduced to be lower than an atmospheric pressure, and the outer layer formed of heat insulating porous material. Therefore, heat insulating properties of the heat insulating layer can be enhanced.

Specifically, the heat exchanging tube is formed by winding the hollow tube around the thermosiphon. That is, a length of a portion of the heat exchanging tube where the heat exchange between the frozen cold storage medium and the liquid phase cooling medium takes place can be elongated. In case of forming the heat exchanging tube using any of copper, copper alloy, aluminum, aluminum alloy, heat conductivity thereof can be improved. Alternatively, In case of forming the heat exchanging tube using synthetic resin, a cost of the material can be reduced.

According to the fifth example, the soil layer is frozen by another heat pipe under the condition in which the temperature of the moisture contained in the soil layer is higher than the external temperature, and the external temperature is lower than a predetermined operating temperature of said another heat pipe. In this case, therefore, cold storage property of the auxiliary cooling device can be further enhanced.

In addition, according to the fifth example, the thermosiphon is also used as said another heat pipe buried in the soil layer. Therefore, the external heat cannot enter into the soil layer through the thermosiphon so that the frozen moisture of the soil layer can be prevented from being melted by the external heat.

Specifically, the soil layer is formed to have a sufficient thickness to maintain the cold energy in the auxiliary cooling device all through the year even during summer, e.g., to have approximately 1 meter thickness. Therefore, a permafrost layer can be formed around the tank of the auxiliary cooling device by freezing the soil layer. The cold energy of the permafrost layer can be utilized to cool the electronic component by arranging the heat exchanger around the thermosiphon buried in the soil layer.

In addition, a configuration of the heat exchanging tube can be simplified by shaping the heat exchanging tube into a U-shape. In this case, a length of the heat exchanging tube can be shortened.

According to the sixth example, the assist heat pipe is arranged in the housing to radiate the heat in the housing to the atmosphere. Therefore, if the air conditioner is arranged in the housing, a burden of the air conditioner can be lightened. As a result, an electric consumption and CO_2 emission of the air conditioner can be reduced. Specifically, one of the end portions of the assist heat pipe is situated above the servers, and the other end portion of the assist heat pipe is exposed to the atmosphere. Therefore, in addition to the above-explained advantage, the heat of the servers in the housing can be radiated efficiently to the atmosphere through the assist heat pipe.

According to the present invention, the auxiliary cooling device is applied to a data center located in the cold region where a freezing index is higher than 400 degree C.·day. Therefore, cooling efficiency of the thermosiphon can be improved so that the cooling medium or the cold storage medium stored in the tank of the auxiliary cooling device can be frozen.

Thus, according to the present invention, the auxiliary cooling device is configured to store the cold energy by radiating the heat of the cooling medium or the cold storage medium stored therein to the atmosphere through the heat pipe thereby freezing the cooling medium or the cold storage medium, under the condition in which the temperature of the cooling medium or the cold storage medium is higher than an external temperature and the external temperature is lower than a predetermined temperature. Therefore, the auxiliary cooling device is capable of storing the cold energy therein without consuming electricity, that is, free of cost. In addition, the auxiliary cooling device is capable of storing the cold energy without emitting greenhouse gas such as CO_2. This means that the datacenter using the auxiliary cooling device of the present invention will not harm the environment. Moreover, the auxiliary cooling device is configured to store the cold energy by freezing the cooling medium or the cold storage medium stored therein. Therefore, in addition to the above-explained advantages, a capacity of the auxiliary cooling device for storing the cold energy with respect to an instillation area is larger than a cold storage device using a liquid phase cooling medium. For this reason, the auxiliary cooling device can be downsized so that a construction cost and an installation area thereof can be reduced. That is, even if a conventional cold storage device has already been used in a cooling system for a datacenter, the conventional cold storage device can be replaced easily with the auxiliary cooling device of the present invention without expanding the installation area of the cooling system. In addition, a capacity of the auxiliary cooling device can be increased by merely increasing the number of tanks without introducing additional air conditioner or chiller units.

BRIEF DESCRIPTION OF THE DRAWINGS

Features, aspects, and advantages of exemplary embodiments of the present invention will become better understood with reference to the following description and accompanying drawings, which should not be read to limit the invention in any way.

FIG. **1** is a schematic view showing an exemplary structure of the cooling system for a datacenter according to the first example of the present invention;

FIG. **2** is a schematic view showing an exemplary structure of the cooling system for a datacenter according to the second example of the present invention;

FIG. **3** is a schematic view showing an exemplary structure of the cooling system for a datacenter according to the third example of the present invention;

FIG. **4** is a schematic view showing an exemplary structure of the cooling system for a datacenter according to the fourth example of the present invention;

FIG. **5** is a schematic view showing an installation example of the cooling system for a datacenter shown in FIG. **4**;

FIG. **6** is a schematic view showing an outlook of the auxiliary cooling device used in the cooling system shown in FIG. **4**;

FIG. **7** is a sectional view showing a longitudinal section of the auxiliary cooling device shown in FIG. **6**;

FIG. **8** is a close-up showing the cross section shown in FIG. **7** partially in an enlarged scale;

FIG. **9** is a schematic view showing an example of the heat exchanging tube used in the auxiliary cooling device shown in FIG. **6**;

FIG. **10** is a schematic view showing a state in which the cooling medium around the exchanging tube shown in FIG. **9** is frozen;

FIG. **11** is a schematic view showing an exemplary structure of the cooling system for a datacenter according to the fifth example of the present invention;

FIG. **12** is a schematic view showing an outlook of the auxiliary cooling device used in the cooling system for a data center shown in FIG. **11**;

FIG. **13** is a sectional view showing a longitudinal section of the auxiliary cooling device shown in FIG. **12**;

FIG. **14** is a sectional view showing a cross section of the auxiliary cooling device shown in FIG. **12**;

FIG. **15** is a schematic view showing a configuration of the thermosiphon type heat pipe arranged in the soil layer;

FIG. **16** is a schematic view showing a modification of the auxiliary cooling device shown in FIGS. **12**, **13** and **14**;

FIG. **17** is a schematic view showing another modification of the auxiliary cooling device shown in FIGS. **12**, **13** and **14**;

FIG. **18** is a sectional view showing a cross section of the auxiliary cooling device shown in FIG. **17**; and

FIG. **19** is a schematic view showing an example of arranging the assist heat pipe of the sixth example in the housing.

DETAILED DESCRIPTION

Hereinafter, exemplary embodiments of the present invention will be explained with reference to the accompanying drawings. FIG. **1** is a schematic view showing an exemplary structure of the cooling system for a datacenter according to the first example. In the datacenter **1**, the plurality of server racks **3** housing the computer servers is installed in a housing **2**. In this example, any kind of appropriate building can be used as the housing **2**. Each of the servers comprises a plurality of electronic components **8** arranged on a printed-circuit board, and those electronic components **8** produce heat as a result of being energized to carry out data processing. For example, the electronic component **8** includes a central processing unit (abbreviated as CPU), a memory device, an electric power source and so on. Those electronic components **8** are contacted individually with a cold plate **9** to exchange the heat therebetween. Therefore, the electronic components **8** are cooled directly by the cold plates **9**.

Specifically, the cold plate **9** is a hollow metal plate, and the cooling medium is allowed to flow through the hollow space. In order to transfer an external heat to the cooling medium flowing through the hollow portion of the cold plate **9**, the cold plate **9** is preferably made of material having good heat conductivity. Therefore, according to the first example, the cold plate **9** is made of copper or copper alloy. The cold plate **9** is connected with a heat exchanger **10** through pipelines forming a cooling circuit C**1**. Therefore, the heat of the cold plate **9** can be transported to the heat exchanger **10** by the cooling medium circulating in the cooling circuit C**1**.

The heat exchanger **10** is configured to exchange heat between high temperature cooling medium flowing therethrough and low temperature cooling medium flowing therethrough, and for example, a plate type heat exchanger or the like can be used as the heat exchanger **10**. In order to transport the heat, the cooling medium is selected from water, water solution containing predetermined amount of anticorrosion additive, ethylene glycol based or calcium chloride based brine whose freezing point is lower than 0 degrees C. (i.e., antifreeze liquid), hydrochlorofluorocarbon such as R-134 or the like.

The temperature of the cooling medium in the cooling circuit C**1** is raised as a result of drawing the heat from the electronic component **8**, and the cooling medium thus heated by the heat of electronic component **8** is flown from the cold plate **9** toward the heat exchanger **10**. In the heat exchanger **10**, the heat of the cooling medium in the circuit C**1** is transferred to low temperature cooling medium circulating in an after-mentioned auxiliary cooling circuit C**2**. The cooling medium in the cooling circuit C**1** thus cooled in the heat exchanger **10** is returned to the cold plate **9** to cool the electronic component **8**.

The heat exchanger **10** is also connected with a chiller unit **11** functioning as a main cooling device through pipelines forming the auxiliary cooling circuit C**2**. Therefore, the heat of the cooling medium circulating in the cooling circuit C**1** can be transported from the heat exchanger **10** to the chiller unit **11** by the cooling medium circulating in the auxiliary cooling circuit C**2**. Specifically, the chiller unit **11** is a heat pump comprising: an internal circuit in which cooling medium such as hydrochlorofluorocarbon circulates therethrough; a compressor **12** which compress the cooling medium by applying a pressure to the cooling medium; a condenser **13** which transports heat of the compressed cooling medium to outside thereby condensing the cooling medium; an expansion valve **14** which expands the condensed cooling medium thereby lowering the temperature of the cooling medium; and an evaporator **15** at which external heat is conducted to the condensed cooling medium. Thus, the chiller unit **11** is configured to transport the heat in the form of latent heat by compressing and expanding the cooling medium circulating therein. For example, a conventional turbo refrigerator and a screw type chiller using hydrochlorofluorocarbon as the cooling medium, an absorption refrigerator using water as the cooling medium and so on can be used as the chiller unit **11**.

A temperature of the cooling medium circulating in the auxiliary cooling circuit C**2** is raised in the heat exchanger **10** as a result of receiving the heat of the cooling medium circulating in the cooling circuit C**1**. Then, the cooling medium in the auxiliary cooling circuit C**2** thus warmed in the heat exchanger **10** is flown toward the chiller unit **11** via an after-mentioned auxiliary cooling device **18**, and the heat thereof is absorbed at the evaporator **15** by the cooling medium circulating in the internal circuit of chiller unit **11**. The cooling medium in the auxiliary circuit C**2** thus cooled in the chiller unit **11** is then returned to the heat exchanger **10**, and the cold energy thereof is transferred to the cooling medium in the cooling circuit C**1**. Consequently, the electronic component **8** is cooled by the cold energy of the cooling medium circulating in the cooling circuit C**1** through the cold plate **9**.

The condenser **13** of the chiller unit **11** is connected with a cooling tower **16** erected outside of the cooling system through pipelines forming a radiating circuit C**3**, and cooling water is circulated in the radiating circuit C**3**. Therefore, the heat of the cooling medium circulating in the internal circuit of the chiller unit **11** is transmitted to the cooling water circulating in the radiating circuit C**3** at the condenser **13**. The heat thus transmitted to the cooling water in the radiating circuit C**3** is radiated from the cooling tower **16** to the atmosphere by a fan **17**.

In order to cool the cooling medium warmed in the heat exchanger **10** prior to arriving at the chiller unit **11**, the auxiliary cooling device **18** is arranged in the auxiliary cooling circuit C**2** on the route from the heat exchanger **10** to the chiller unit **11**. For this purpose, the auxiliary cooling device **18** is provided with: a tank **19** which reserves the cooling medium therein temporarily; and a plurality of heat pipes **20** which radiate the heat of the cooling medium in the tank **19** to the atmosphere.

Specifically, the tank **19** is a watertight hollow container. Therefore, the water outside of the tank will not penetrate into the tank **19** and the cooling medium in the tank **19** will not leak from the tank **19**. As described, a role of the tank **19** is to reserve the cooling medium temporarily thereby cooling the cooling medium in advance of reaching the chiller unit **11**. Therefore, the tank **19** is preferably insulated from the external heat. For this reason, the tank **19** is formed of low-heat conductive material such as concrete. In order to protect the tank **19** from the external heat, it is preferable to bury the tank **19** in the ground.

In addition, a plurality of flow channels **21** is formed on a bottom of the tank **19**. More specifically, the flow channel **21** is a grove between ribs **22** for letting through the cooling medium. Therefore, in the auxiliary cooling device **18**, the cooling medium flowing from the heat exchanger **10** is allowed to flow through the flow channels **21** unidirectionally toward the chiller unit **11**. In each of the flow channel **21**, the heat pipes **20** are erected substantially vertically at predetermined intervals. Specifically, one of end portions of the heat pipe **20** immersed into the cooling medium in the tank **19** serves as an evaporating portion **20***a* at which working fluid encapsulated therein is evaporated. The other end portion of the heat pipe **20** is exposed to the outside of the tank **19** to be contacted with the external air. That is, the other end portion **20***b* serves as a condensing portion at which the vaporized working fluid in the heat pipe **20** is condensed by radiating the heat of the vaporized working fluid to the atmosphere. For this purpose, a plurality of radiating fins **23** is arranged on the condensing portion **20***b*.

Specifically, the heat pipe **20** is a thermosiphon comprising an evacuated hollow container, and volatile and condensable working fluid contained in the container air-tightly. In order to exchange internal heat and external cold energy efficiently, the container of the heat pipe **20** is preferably made of material having good heat conductivity such as copper. Preferably, the heat pipe **20** is configured to be activated under the condition where the external temperature is lower than 10 degrees C. For this purpose, the working fluid of the heat pipe **20** is selected from ammonia and hydrochlorofluorocarbon such as R-134 or the like whose boiling point is lower than 10 degrees C., and 20 to 30 volume percent of the working fluid is contained in the heat pipe **20**.

Therefore, provided that the external temperature is lower than 10 degrees C., and the temperature of the cooling medium in the tank **19** is higher than 10 degrees C., the working fluid is vaporized in the evaporating portion **20***a*. The vapor of the working fluid rises toward the condensing portion **20***b* where the temperature and the pressure are lower than those in the evaporating portion **20***a*, and the heat in the tank **19** thus transported to the condensing portion **20***b* by the vaporized working fluid is then radiated to the atmosphere thorough the fins **23**. As a result, the cooling medium in the tank **19** is cooled and the temperature thereof is lowered. The vaporized working fluid is condensed again in the condensing portion **20***b* and returned gravitationally to the evaporating portion **20***a*. Thus, a thermal diode characteristic of the heat pipe **20** ensures to transport the heat unilaterally from evaporating portion **20***a* toward the condensing portion **20***b* thereby radiating the heat of the cooling medium in the tank **19** unilaterally to the outside of the tank **19**. Conversely, in case the external temperature is higher than 10 degrees C., the heat pipe **20** will not be activated. In this case, therefore, the external temperature is prevented from entering into the tank **19** so that the temperature of the cooling medium in the tank **19** will not be raised by the external temperature.

Additionally, it is possible to arrange a wick in the evaporating portion **20***a* of the heat pipe **20** from a level of the cooling medium in the tank **19** to a bottom of the heat pipe **20**. In this case, the liquid phase working fluid in the evaporating portion **20***a* is soaked up to an upper end of the wick by capillary action of the wick. Therefore, the portion of the heat pipe **20** in which the wick is thus arranged is allowed to serve as the evaporating portion **20***a* entirely even if a level of the liquid phase working fluid in the evaporating portion **20***a* becomes lower than the level of the cooling medium in the tank **19**. However, the thermal diode characteristics of the heat pipe **20**, that is, the direction to transport the heat will not be changed even if the wick is thus arranged in the evaporating portion **20***a*.

Thus, according to the first example, the heat of the electronic component **8** is drawn by the cooling medium circulating in the cooling circuit C**1**. The heat of the electronic component **8** transmitted to the cooling medium circulating in the cooling circuit C**1** is then transported to the heat exchanger **10**, and transferred to the cooling medium circulating in the auxiliary cooling circuit C**2** cooled by the chiller unit **11**. The cooling medium in the cooling circuit C**1** thus cooled in the heat exchanger **10** is returned toward the electronic component **8**. Meanwhile, the cooling medium in the auxiliary cooling circuit C**2** warmed in the heat exchanger **10** by the cooling medium in the cooling circuit C**1** is returned to the chiller unit **11** while being cooled by the auxiliary cooling device **18** on the way.

Specifically, the heat of the cooling medium in the auxiliary cooling circuit C**2** being returned from the heat exchanger **10** to the chiller unit **11** is dissipated to the atmosphere in advance through the heat pipes **20** in the auxiliary cooling device **18**. That is, the cooling medium in the auxiliary cooling circuit C**2** is cooled by the auxiliary cooling device **18** prior to cooling by the chiller unit **11**. Therefore, the temperature of the cooling medium in the auxiliary cooling circuit C**2** returned to the chiller unit **11** has already been lowered to a certain level so that the burden on the chiller unit **11** can be lightened, in comparison with a case in which the cooling medium is returned directly to the chiller unit **11** without passing through the auxiliary cooling device **18**. For this reason, a running cost of the chiller unit **11** and CO_2 emission from the chiller unit **11** can be reduced, and in addition, the chiller unit **11** can be downsized.

When the temperature of the cooling medium being returned from the heat exchanger **10** to the chiller unit **11** is lowered to a desired temperature, e.g., below 10 degrees C., the chiller unit **11** can be stopped. In this case, the cooling medium circulating in the auxiliary cooling circuit C**2** can be cooled sufficiently by merely radiating the heat thereof through the heat pipes **20** in the auxiliary cooling device **18**, and the electronic component **8** can be cooled by the cooling medium in the cooling circuit C**1** cooled by the cooling medium in the auxiliary cooling circuit C**2**. In this case, therefore, the running cost of the chiller unit **11** can be eliminated and CO_2 will not be emitted from the chiller unit **11**. In addition, the auxiliary cooling device **18** is thus configured to cool the cooling medium without using mechanical devices such as the condenser **13** and the compressor **12** used in the chiller unit **11**. Therefore, the structure of the auxiliary cooling device **18** is very simple so that maintenance of the auxiliary cooling device **18** is substantially unnecessary. Here, in order to circulate the cooling medium compulsory in the circuits C**1**, C**2** and C**3**, a pump may be arranged on each of the circuits C**1**, C**2** and C**3**. In addition, the servers can also be connected directly with the auxiliary cooling unit **18** and the chiller unit **11** without interposing the heat exchanger **10** therebetween.

Here will be explained the second example of the present invention with reference to FIG. **2**. According to the second example, the server racks **3** are also installed in the housing **2** of the datacenter **1**, and the cold plate **9** is contacted with the electronic component **8**. The cold plate **9** is also connected with the heat exchanger **10** through the pipelines forming a circuit between the heat exchanger **10** and the electronic component **8**, and the cooling medium is circulated in the circuit. According to the second example, in order to absorb or to buffer a volume change in the cooling medium, an expansion tank **24** is arranged on the pipeline for returning the cooling medium from the cold plate **9** to the heat exchanger **10**. Therefore, the cooling medium expanded by the heat of the electronic component **8** can be temporarily reserved in the expansion tank **24**. Although not especially shown in FIG. **2**, the expansion tank **24** is preferably connected with the circuit through an appropriate relief valve. In addition, in order to circulate the cooling medium compulsory in the circuit, a pump **25** is arranged between the expansion tank **24** and the heat exchanger **10**. Here, a conventional pump can be used as the pump **25**.

The heat exchanger **10** is connected with a mixing tank **26** through a pipe line. Specifically, the mixing tank **26** is configured to regulate the temperature of the cooling medium therein stepwise by mixing hot cooling medium and cold cooling medium supplied thereto from both sides. For this purpose, according to the third example, the mixing tank **26** is divided into six mixing chambers **26***a* to **26***f*. The adjoining mixing chambers are connected via through holes **28** formed alternately in vertical direction. For example, the through hole **28** connecting the mixing chambers **26***a* and **26***b* is formed in a lower side of the mixing tank **26**, and the through hole **28** connecting the mixing chambers **26***b* and **26***c* is formed in an upper side of the mixing chamber **26**.

Specifically, the mixing chamber **26***a* is connected with the heat exchanger **10** through a pipeline, and the cooling medium heated in the heat exchanger **10** is supplied to the mixing chamber **26***a*. Meanwhile, the mixing chamber **26***f* is connected with the chiller unit **11** functioning as the main cooling device and with an ice storage device **27** functioning as the auxiliary cooling device through pipelines. Therefore, the cooling mediums cooled by the chiller unit **11** and the ice storage device **27** are supplied to the mixing chamber **26***f*. The mixing chamber **26***a* is also connected with the ice storage device **27** and with the chiller unit **11** through pipelines. Therefore, the cooling medium is supplied to the chiller unit **11** selectively from the mixing chambers **26***a* and **26***f*. The cooling medium cooled in the chiller unit **11** is returned to the mixing chamber **26***f*.

In addition, the mixing chamber **26***a* is also connected with the heat exchanger **10** through a pipeline, and the mixing chamber **26***f* is also connected with the heat exchange **10** through another pipeline. Therefore, the cooling medium whose temperature is regulated stepwise in the mixing chambers **26***a* to **26***f* is supplied to the heat exchanger **10** selectively from the mixing chambers **26***a* and **26***f*.

Next, a function of the mixing chamber **26** will be explained hereinafter. As described, the cooling medium heated in the heat exchanger **10** is supplied to the mixing chamber **26***a*, and flows toward the mixing chamber **26***f* via the mixing chambers **26***b*, **26***c*, **26***d* and **26***e*. Conversely, the cooling mediums cooled by the chiller unit **11** and the ice storage device **27** are supplied to the mixing chamber **26***f*, and flows toward the mixing chamber **26***a* via the mixing chambers **26***e*, **26***d*, **26***c* and **26***b*. Therefore the cooling medium having higher temperature supplied to the mixing chamber **26***a* from the heat exchanger **10** is mixed with the cooling medium having lower temperature flowing from the mixing chamber **26***f*. As a result, the cooled cooling medium is convectively submerged toward the lower side of the mixing chamber **26***a*, and warmed cooling medium is convectively raised toward the upper side of the mixing chamber **26***a*. Then, the cooled cooling medium thus migrates to the lower side of the mixing chamber **26***a* flows into the adjoining mixing chamber **26***b* through the through hole **28** formed in a lower side of a partition wall between the mixing chambers **26***a* and **26***b*. The cooling medium thus flowing into the mixing chamber **26***b* from the mixing chamber **26***a* is mixed with the cooling medium having lower temperature flowing into the mixing chamber **26***b* from the mixing chamber **26***c*. As a result, the warmed cooling medium is convectively raised toward the upper side of the mixing chamber **26***b*, and the cooled cooling medium is convectively submerged toward the lower side of the mixing chamber **26***b*. Then, the cooled cooling medium thus migrates to the upper side of the mixing chamber **26***b* flows into the adjoining mixing chamber **26***c* through the through hole **28** formed in an upper side of a partition wall between the mixing chambers **26***b* and **26***c*. Thus, the high temperature cooling medium supplied to the mixing chamber **26***a* flows convectively toward the mixing chamber **26***f* while being cooled gradually.

Conversely, the cooling mediums cooled in the ice storage device **27** and the chiller unit **11** are supplied to the mixing chamber **26***f* as described. The cooling medium having lower temperature supplied to the mixing chamber **26***f* is mixed with the cooling medium having higher temperature flowing into the mixing chamber **26***f* from the mixing chamber **26***e*, and the cooling medium having lower temperature is convectively submerged toward the lower side of the mixing chamber **26***f*. Then, the cooling medium migrates to the lower side of the mixing chamber **26***f* and flows into the adjoining mixing chamber **26***e* through the through the hole **28** formed in a lower side of a partition wall between the mixing chambers **26***f* and **26***e*. The cooling medium thus flowing into the mixing chamber **26***e* from the mixing chamber **26***f* is mixed with the cooling medium having higher temperature flowing into the mixing chamber **26***e* from the mixing chamber **26***d*. As a result, the warmed cooling medium is convectively raised toward the upper side of the mixing chamber **26***e*, and flows into the adjoining mixing chamber **26***d* through the through hole **28** formed in an upper side of a partition wall between the mixing chambers **26***e* and **26***d*. Thus, the low temperature cooling medium supplied to the mixing chamber **26***f* flows convectively toward the mixing chamber **26***a* while being warmed gradually. That is, the cooling medium in the cooling chamber **26***a* is at the highest temperature, and the temperature of the cooling medium is lowered gradually from the mixing chambers **26***b* to **26***f*.

The cooling medium whose temperature is thus regulated in the mixing chamber **26***a* is partially supplied to the ice storage device **27**. For this purpose, a pump **29** is arranged on the pipeline connecting the mixing chamber **26***a* with the ice storage device **27**. Specifically, the ice storage device **27** is configured to cool or freeze the cooling medium supplied thereto from the mixing tank **26** by radiating the heat of the cooling medium to the atmosphere. In other words, the ice storage device **27** is configured to store the cold energy by cooling or freezing the cooling medium stored therein by external cold energy. The cold energy of the ice stored in the ice storage device **27** is used to cool the cooling medium supplied thereto from the mixing chamber **26***a*, and transported to the mixing chamber **26***f* by the cooled liquid phase cooling medium. Therefore, in order to cool the datacenter **1** effectively, the mixing tank **26** and the ice storage device **27** are preferably installed in a cold region where a freezing index is higher than 400 degree C.·day.

Specifically, the ice storage device **27** comprises: a tank **30** which reserves the cooling medium supplied from the mixing chamber **26***a* temporarily; and a heat pipe **31** which cools and freezes the cooling medium stored in the tank **30** by radiating the heat of the cooling medium to the atmosphere. The tank **30** is a watertight hollow container, therefore, the water outside of the tank **30** will not penetrate into the tank **30** and the cooling medium in the tank **30** will not leak from the tank **30**. In addition, the tank **30** is preferably insulated from the external heat. Therefore, tank **30** is preferably formed of low-heat conductive material such as concrete, and buried in the ground.

The heat pipe **31** is erected substantially vertically in the tank **30**, and one of the end portions of the heat pipe **31** immersed into the cooling medium in the tank **30** serves as an evaporating portion **31***a* at which working fluid encapsulated therein is evaporated. The other end portion of the heat pipe **31** is exposed to outside of the tank **30** to be contacted with the atmosphere. That is, the other end portion **31***b* serves as a condensing portion at which the vaporized working fluid in the heat pipe **31** is condensed by radiating the heat of the vaporized working fluid to the atmosphere. For this purpose, a plurality of radiating fins **32** are arranged on the condensing portion **31***b*.

As in the first example, a thermosiphon is also used in the second example as the heat pipe **31**. Therefore, a direction of the heat pipe **31** to transport the heat is restricted to one direction by the thermal diode characteristics thereof so that the external heat will not enter into the tank **30** through the heat pipe **31**. The working fluid encapsulated in the heat pipe **31** is also selected from ammonia and hydrochlorofluorocarbon such as R-134 or the like whose boiling point is lower than 10 degrees C.

Therefore, the working fluid in the heat pipe **31** is vaporized in the evaporating portion **31***a* under the condition where the external temperature is lower than 10 degrees C., and vapor of the working fluid rises toward the condensing portion **31***b*. The heat of the cooling medium is thus transported to the condensing portion **31***b* by the vaporized working fluid in the form of latent heat, and radiated to the atmosphere through the fins **32**. As a result, the vaporized working fluid is condensed again and returned gravitationally to the evaporating portion **31***a*. Thus, the cooling medium in the ice storage device **27** is cooled by the external cold energy under the condition where the external temperature is lower than 10 degrees C., and frozen under the condition where the external temperature becomes lower than zero. As described, the vaporized working fluid is condensed in the condensing portion **31***b* and returned gravitationally to the evaporating portion **31***a*. Therefore, a content of the liquid phase working fluid in the condensing portion **31***b* is much smaller than that of the liquid phase working fluid in the evaporating portion **31***a*. For this reason, the external heat will not be transported from the top side of the heat pipe **31**, that is, from the condensing portion **31***b* to the evaporating portion **31***a* even if the external temperature is higher than 10 degrees C. Thus, the working fluid in the tank **30** can be prevented from being warmed by the external heat.

As described, the heat exchanger **10** is connected with the mixing chambers **26***a* and **26***f* through the pipelines, and a switching valve **33** is arranged at a junction of the pipe line connecting the mixing chambers **26***a* and **26***f*, and the pipeline connecting the heat exchanger **10** and the pipe line connecting the mixing chambers **26***a* and **26***f*. Therefore, the cooling medium cooled in the mixing tank **26** can be supplied to the heat exchanger **10** selectively from the mixing chambers **26***a* and **26***f*. For example, an electromagnetic 3-way valve activated electrically to switch the flow channel can be used as the switching valve **33**.

In order to supply the cooling medium from the mixing chambers **26***a* and **26***f* to the heat exchanger **10**, and to return the cooling medium from the heat exchanger **10** to the mixing chamber **26***a*, a pump **34** is arranged between the heat exchanger **10** and the switching valve **33**. In this example, a conventional feeding pump is used as the pump **34**.

In addition, although not shown in FIG. **2**, the cooling system of the second example is further provided with a temperature detecting means adapted to detect the temperatures of the cooling mediums in the mixing chambers **26***a* and **26***f*, and a control means adapted to control the switching valve **33** and a below-explained switching valve **35** according to the temperature detected by the temperature detecting means. Therefore, the switching valve **33** is activated to switch a supply source of the cooling medium to the heat exchanger **10** between the mixing chambers **26***a* and **26***f*, in accordance with a signal from the control means representing the temperatures of the cooling mediums in the mixing chambers **26***a* and **26***f*. Specifically, in case the temperature of the cooling medium in the mixing chamber **26***a* is higher than a predetermined temperature, the switching valve **33** allows the cooling medium in the mixing chamber **26***f* to be supplied to the heat exchanger **10**. Conversely, in case the temperature of the cooling medium in the mixing chamber **26***a* is lower than a predetermined temperature, the switching valve **33** allows the cooling medium in the mixing chamber **26***a* to be supplied to the heat exchanger **10**. Alternatively, in order to switch the flow channels in the above-described manner to supply the cooling medium to the heat exchanger **10**, a valve configured to be switched by a motor or the like may also be used as the switching valve **33** instead of the electromagnetic valve. Thus, the switching valve **33** serves as the first switching valve of the present invention.

As described, the chiller unit **11** is also connected with the mixing chambers **26***a* and **26***f* through the pipelines, and a switching valve **35** is arranged at a junction of the pipe line connecting the mixing chambers **26***a* and **26***f*, and the pipeline connecting the chiller unit **11**. Therefore, the cooling medium in the mixing tank **26** can also be supplied to the chiller unit **11** selectively from the mixing chambers **26***a* and **26***f*, and the cooling medium cooled in the chiller unit **11** is returned to the mixing chamber **26***f*. Here, the structure of the switching valve **35** is identical to that of the switching valve **33**. Therefore, in case the temperature of the cooling medium in the mixing chamber **26***f* is higher than a predetermined temperature, the switching valve **35** is switched by the control means in a manner to allow the cooling medium in the mixing chamber **26***f* to be supplied to the chiller unit **11**. Conversely, in case the temperature of the cooling medium in the mixing chamber **26***f* is lower than a predetermined temperature, the switching valve **35** is switched by the control means in a manner to allow the cooling medium in the mixing chamber **26***a* to be supplied to the chiller unit **11**. Thus, the switching valve **35** serves as the second switching valve of the present invention.

In order to supply the cooling medium to the chiller unit **11** from the mixing chambers **26***a* and **26***f*, and to return the cooling medium from the chiller unit **11** to the mixing chamber **26***f*, a pump **36** is arranged between the switching valve **35** and the chiller unit **11**. Here, a conventional pump is also used to serve as the pump **36**.

As in the first example, the chiller unit **11** is also connected with the cooling tower **16** erected outside of the cooling system through pipelines forming a circuit, and in order to circulate cooling water in the circuit, a pump **37** is arranged on the pipeline for feeding the cooling water from the chiller unit **11** to the cooling tower **16**. Therefore, the heat of the chiller unit **11** is transported to the cooling tower **16** by the cooling water, and radiated to the atmosphere from the cooling tower **16** by the fan **17**.

Thus, according to the second example of the present invention, the heat of the electronic component **8** is transported to the heat exchanger **10** by the cooling medium circulating in the circuit connecting the cold plate **9** and the heat exchanger **10**. The heat thus transported to the heat exchanger **10** is transferred to the cooling medium supplied to the heat exchanger **10** from the mixing chamber **26***a* or **26***f* which is cooled by the ice storage device **27** or by the chiller unit **11**. The cooling medium warmed in the heat exchanger **10** is returned to the mixing chamber **26***a* of the mixing tank **26**, and gradually cooled in the mixing tank **26** while flowing across the mixing chambers **26***a* to **26***f* to be mixed convectively with the cooling medium flowing from the mixing chamber **26***f* which is cooled by the ice storage device **27** or the chiller unit **11**. Then, the cooling medium whose temperature is thus neutralized in the mixing tank **26** is supplied again to the ice storage device **27** and to the chiller unit **11**. Therefore, according to the second example, the cold energy in the ice storage device **27** will not be wasted excessively, that is, the ice stored in the ice storage device **27** will not be melted excessively. In addition to the above-explained advantage, the burden of the chiller unit **11** can be lightened so that the running cost of the chiller unit **11** and CO_2 emission can be reduced. Conversely, according to the cooling system of the second example, it is also possible to warm the cooling medium in the mixing tank **26** in advance, and supply the warmed cooling medium to the heat exchanger **10**. In this case, the electronic component **8** can be prevented from being cooled excessively.

That is, according to the cooling system of the second example, temperature of the cooling medium to be supplied to the heat exchanger **10**, the chiller unit **11** and the ice storage device **27** can be optimized in the mixing tank **26** before supplied to those elements. Therefore, thermal efficiency of the cooling system can be improved. In addition, the temperature of the cooling medium to be supplied to the heat exchanger **10**, the chiller unit **11** and the ice storage device **27** from the mixing tank **26** can be adjusted more finely by changing a number of the mixing chambers in the mixing tank **26**. Further, according to the second example of the present invention, the electronic component **8** can be cooled only by the ice storage device **27** even if the chiller unit **27** is in trouble or electric power supply to the chiller unit **11** is interrupted.

Next, the third example of the present invention will be explained hereinafter with reference to FIG. **3**. Specifically, the third example of the present invention relates to an auxiliary cooling device, which is configured to cool the datacenter **1** in case the chiller unit **11** functioning as the main cooling device is in trouble due to electric power outage or the like.

According to the third example, the server racks **3** are also installed in the container **2** of the datacenter **1**. The cold plate **9** is also contacted with the electronic component **8** and connected with the heat exchanger **10** through the pipelines forming a circuit, and the pump **25** is arranged on the pipeline for returning the cooling medium from the cold plate **9** to the heat exchanger **10**. Therefore, the cooling medium can be circulated in the circuit connecting the cold plate **9** and the heat exchanger **10**.

According to the third example, the heat exchanger **10** is connected with the evaporator **15** of the chiller unit **11** thorough pipelines forming a circuit, and in order to circulate the cooling medium in the circuit, a pump **38** is arranged on the pipeline for supplying the cooling medium from the chiller unit **11** to the heat exchanger **10**. Therefore, the heat of the electronic component **8** is transferred to the cold plate **9**, and the heat transferred to the cold plate **9** is transported to the heat exchanger **10** by the cooling medium. The heat of the cooling medium thus transported to the heat exchanger **10** from the cold plate **9** is then transferred to the cooling medium having lower temperature supplied to the heat exchanger **10** from the chiller unit **11**. As a result, the electronic component **8** is cooled by the cold plate **9**.

Meanwhile, the condenser **13** of the chiller unit **11** is connected with the cooling tower **16** through pipelines forming a circuit, and in order to circulate cooling water in the circuit, a pump **37** is arranged on the pipeline for supplying the cooling medium from the condenser **13** to the cooling tower **16**. The heat of the cooling medium warmed in the condenser **13** is transported to the cooling tower **16**, and radiated to the atmosphere by the fan **17**.

In the circuit connecting the heat exchanger **10** and the chiller unit **11**, a switching valve **39** is arranged at a junction of the pipeline for supplying the cooling medium from the heat exchanger **10** to the evaporator **15** and a pipeline for supplying the cooling medium from said pipeline to an ice storage device **41** functioning as an auxiliary cooling device. In addition, a switching valve **40** is arranged at a junction of the pipeline for supplying the cooling medium from the evaporator **15** to the heat exchanger **10** and a pipeline for supplying the cooling medium from the ice storage device **41** to said pipeline. Therefore, according to the third example, the ice storage device **41** can be used as the cold source for cooling the datacenter **1** instead of the chiller unit **11**, in case the chiller unit **11** has some kind of trouble.

Thus, the cooling medium warmed in the heat exchanger **10** is allowed to flow selectively to the chiller unit **11** and to the ice storage device **41** by switching the switching valve **39**. Likewise, the cooling medium cooled in the chiller unit **11** is allowed to flow selectively to the heat exchanger **10** and to the ice storage device **41** by switching the switching valve **40**.

Although not especially shown in FIG. **3**, according to the third example, the cooling system is provided with: a detecting means adapted to detect a change in the temperature of the datacenter **1** and to detect a trouble in the chiller unit **11**; and a control means adapted to switch the switching valves **39** and **40** on the basis of a detection signal from the detecting means. Therefore, in case the temperature in the datacenter **1** detected by the detecting means is higher than a predetermined temperature, or in case a trouble in the chiller unit **11** is detected by the detecting means, the switching valve **39** is switched by the control means to allow the cooling medium in the heat exchanger **10** to flow toward the ice storage device **41**, and the switching valve **40** is switched by the control means to allow the cooling medium in the ice storage device **41** to flow toward the heat exchanger **10**. As described, an electromagnetic valve can be used as the switching valves **39** and **40**. According to the third example, since the aforementioned pump **38** is arranged between the switching valve **40** and the heat exchanger **10**, the cooling medium can be circulated among the heat exchanger **10**, the chiller unit **11** and the ice storage device **41** without arranging additional pumps.

As the examples previously explained, the ice storage device **41** comprises: a tank **42** which reserves the cooling medium therein; and a plurality of heat pipes **43**. In order to insulate the cooling medium stored in the ice storage device **41**, tank **42** is preferably formed of low-heat conductive material such as concrete.

According to the third example, a thermosiphon is also used as the heat pipe **43**. Therefore, a direction of the heat pipe **43** to transport the heat is restricted to one direction, and the external heat will not enter into the tank **41** through the heat pipe **43**. Also, the working fluid encapsulated in the heat pipe **43** is selected from ammonia and hydrochlorofluorocarbon such as R-134 or the like whose boiling point is lower than 10 degrees C., and 20 to 30 volume percent of the working fluid is contained in the heat pipe **43**.

The heat pipe **43** is erected substantially vertically in the tank **42**, and one of the end portions of the heat pipe **43** immersed into the cooling medium in the tank **42** serves as an evaporating portion **43***a* at which working fluid encapsulated therein is heated to be vaporized. The other end portion of the heat pipe **43** is exposed to outside of the tank **42** to be contacted with the atmosphere. That is, the other end portion serves as a condensing portion **43***b* at which the vaporized working fluid in the heat pipe **43** is condensed by radiating the heat of the vaporized working fluid to the atmosphere. For this purpose, a plurality of radiating fins **44** are arranged on the condensing portion **43***b*. The working fluid thus condensed in the condensing portion **43***b* is gravitationally returned to the evaporating portion **43***a*. In order to freeze the cooling medium stored in the tank **42** efficiently, the ice storage device **41** is preferably installed in a cold region where a freezing index is higher than 400 degree C.·day.

In case the temperature of the cooling medium in the ice storage device **41** is higher than the external temperature, and the external temperature becomes lower than a predetermined operating temperature of the heat pipe **43**, the heat of the cooling medium in the tank **42** is transported in the heat pipe **43** from the evaporating portion **43***a* to the condensing portion **43***b*, and radiated to the atmosphere from the fins **44**. As a result, the cooling medium in the tank **42** is cooled to store the cold energy, and in case the external temperature further drops to below freezing point, the cooling medium in the ice storage device **41** is frozen. Conversely, even in case the external temperature becomes higher than the temperature of the cooling medium in the tank **42**, the external heat will not enter into the ice storage device **41** through the heat pipe **43** so that the cooling medium can be prevented from being wasted by the external air.

Thus, according to the third example of the present invention, the cold energy can be stored in the ice storage device **41** utilizing the external cold energy without using electricity. That is, the ice storage device **41** can be operated without running cost and without emitting CO_2 gas. Moreover, the cold energy is stored in the ice storage device **41** in the form of ice. Therefore, the ice storage device **41** can be downsized in comparison with a case of storing the cold energy by merely cooling liquid phase cooling medium so that a construction cost thereof can be reduced. In addition to the above-explained advantages, the cold energy stored in the ice storage device **41** can be supplied to the heat exchanger **10** to cool the heated cooling medium returned to the heat exchanger **10** from the cold plate **9**, in case electric power supply to the chiller unit **11** is interrupted, or in case a failure occurs in the chiller unit **11**. Thus, the ice storage device **41** serves as the auxiliary cooling device of the present invention.

Next, here will be explained a fourth example of the present invention with reference to FIGS. **4** to **10**. The fourth example is a modified example of the auxiliary cooling device used in the third example. Therefore, detailed explanation for the elements in common with the previously explained example is omitted by allotting common reference numerals. FIG. **4** is a schematic view showing an entire structure of the cooling system for a datacenter using the modified auxiliary cooling device according to the fourth example. As shown in FIG. **4**, in the fourth example, the heat exchange **10** is not interposed between the data center **1** and the chiller unit **11** unlike the third example. However, it is possible to interpose the heat exchanger **10** between the data center **1** and the chiller unit **11** according to need.

Specifically, in the fourth example, the cold plate **9** is connected with the chiller unit **11** through a feeding pipe for supplying the cooling medium from the chiller unit **11** to the cold plate **9**, and the switching valve **39** is arranged on the feeding pipe. Therefore, the cooling medium cooled by the chiller unit **11** is supplied to the cold plate **9** via the switching valve **39**. The cold plate **9** is also connected with the chiller unit **11** through a returning pipe for returning the cooling medium from the cold plate **9** to the chiller unit **11**, and the switching valve **40** is arranged on the returning pipe. Therefore, heat of the electric component **8** transferred to the cold plate **9** is transported to the chiller unit **11** by the cooling medium through the returning pipe via the switching valve **40**.

In addition, another feeding pipe of the cooling medium is also extended from the ice storage device **41** and merged with the feeding pipe extending from the chiller unit **11** at the switching valve **39**. Meanwhile, the returning pipe extending from the cold plate **9** is divided at the switching valve **40** to be also connected with the ice storage device **41**. Therefore, it is possible to form a circuit connecting the cold plate **9** and the chiller unit **11**, and a circuit connecting the cold plate **9** and the ice storage device **41** alternately by switching the switching valves **39** and **40**.

In order to force the cooling medium to circulate in each of the circuits, that is, among the cold plate **9**, the chiller unit **11** and the ice storage device **41**, the pump **25** is arranged between the switching valve **39** and the cold plate **9**.

Thus, according the fourth example, the cooling medium can be circulated alternately in the circuit connecting the cold plate **9** and the chiller unit **11**, and in the circuit connecting the cold plate **9** and the ice storage device **41** by switching the switching valves **39** and **40** by the control means. Therefore, the cooling medium heated by the heat of the electronic component **8** in the cold plate **9** can be returned selectively to the chiller unit **11** and the ice storage device **41**, and the cooling medium cooled in the chiller unit **11** or the ice storage device **41** can be supplied to the cold plate **9** selectively depending on the temperature in the data center **1** or depending on an operating condition of the chiller unit **11**.

As shown in FIG. **5**, in order to insulate the ice storage device **41** from the external heat, the ice storage device **41** according to the fourth example is buried in the ground where the temperature change is smaller than that above the ground, and the ice storage device **41** is surrounded by a heat insulating layer **45** below the ground, which in turn is surrounded by a waterproof layer **46**. FIG. **6** is a schematic view showing an outlook of the ice storage device **41** of the fourth example, and FIG. **7** is a sectional view thereof. As shown in FIG. **7**, according to the fourth example, the ice storage device **41** comprises: cold storage medium to be frozen by the external cold energy; the tank **42** which holds cold storage medium therein; a heat insulating layer **45** which insulate the tank **42** from the external heat; a waterproof layer **46** which prevent external water from penetrating into the tank **42**; the plurality of heat pipes **43** which radiates the heat of cold storage medium reserved in the tank **42** to the atmosphere, and a coil shaped heat exchanging tube **49** is wrapped around the evaporating portion **43***a* of the heat pipe **43**. A shape of the tank **42** should not be limited to a specific shape. However, in case of forming the tank **42** into a cylindrical shape as shown in FIG. **6**, a surface area of the tank **42** can be reduced in comparison with a case of forming the tank **42** into a cuboid shape having a same capacity.

FIG. **8** is a close-up showing the cross section of the ice storage device **41** of the fourth example partially in an enlarged scale. As shown in FIG. **8**, the heat insulating layer **45** comprises an inner layer **47** formed of a hollow plate; and an outer layer **48** formed of porous material. Specifically, a conventional hollow vacuum panel in which an internal pressure thereof is lower than an atmospheric pressure can be used as the inner layer **47**, and the outer layer **48** can be formed of expanded polyurethane, expanded polystyrene, glass wool etc.

As described, in order to prevent the external water from penetrating into the tank **42**, the waterproof layer **46** is formed around the outer layer **48**. For example, a waterproof sheet formed of synthetic resin can be used as the waterproof layer **46**.

An example of a coil shaped heat exchanging tube **49** adapted to transport the cold energy from the cold storage medium in the tank **42** is shown in FIG. **9**. Specifically, the heat exchanging tube **49** is a hollow tube wrapped spirally around the evaporating portion **43***a* of the heat pipe **43**, and the liquid phase cooling medium is allowed to flow therethrough. In order to facilitate heat exchange between the heat of the liquid phase cooling medium flowing through the heat exchanging tube **49** and the cold energy of the cold storage medium in the tank **42**, material of the heat exchanger **49** is selected from copper, copper alloy, aluminum, aluminum alloy and so on. A length of the heat exchanging tube **49** can be adjusted according to a required amount of the cold energy for cooling the datacenter **1** to a desired temperature, in other words, according to an amount of the heat to be exchanged between the cooling medium and the cold storage medium thorough the heat exchanging tube **49**. A length of the heat exchanging tube **49** required in the ice storage device **41** can be experimentally found in advance. In addition, in order to reduce a cost of the material, the heat exchanging tube **49** may also formed of synthetic resin. In this case, heat conductivity of the heat exchanging tube **49** has to be degraded, however, such disadvantage can be avoided by elongating the length of the heat exchanging tube **49**.

In case the switching valve **39** and **40** are switched in a manner to connect the cold plate **9** and the ice storage device **41**, the cooling medium heated as a result of drawing the heat of the electronic component **8** in the cold plate **9** is returned to the ice storage device **41** through the aforementioned returning pipe. The cooling medium entering into the heat exchanging tube **49** flows from an upper side of the heat exchanging tube **49** toward a lower side of the heat exchanging tube **49** while transferring the heat thereof to the cold storage medium in the tank **42**. As a result, the liquid phase cooling medium flowing through the heat exchanging tube **49** is cooled by the cold energy of the cold storage medium in the tank **42**, and then supplied to the cold plate **9**.

In case the external temperature drops to below the freeing point, the cold storage medium in the tank **42** is frozen by the external cold energy entering into the tank **42** through the heat pipes **43**. In this case, first the cold storage medium around a surface of the evaporating portion **43***a* starts to be frozen as illustrated by a dotted line in FIG. **10**. Then, the cold storage medium around the heat exchanging tube **49** is frozen, and eventually the cold storage medium in the tank **42** is frozen entirely. The external cold energy is thus stored in the tank **42** in the form of ice.

Specifically, in case the detecting means detects that the temperature in the datacenter **1** is higher than a predetermined temperature, or that the chiller unit **11** cannot be operated, the switching valves **39** and **40** are switched by the control means in a manner to switch a cold energy source used to cool the datacenter **1** from the chiller unit **11** to the ice storage device **41**. In this case, the cooling medium heated by the electronic component **8** in the cold plate **9** is returned to the heat exchanging tube **49** in the ice storage device **41** through the returning pipe. As a result, the heat of the cooling medium flowing through the heat exchanging tube **49** is transferred to the frozen cold storage medium in the tank **42**, and the temperature of the cooling medium is lowered while melting the frozen cold storage medium. The cooling medium thus cooled in the ice storage device **41** is then supplied to the cold plate **9** thorough the feeding pipe thereby cooling the electronic component **8**.

Thus, according to the fourth example of the present invention, the cold energy of the cold storage medium held in the ice storage device **41** can be transported easily by the liquid phase cooling medium flowing through the heat exchanging tube **49**, even when the cold storage medium is frozen. In addition, the ice storage device **41** of the fourth example is buried in the ground, and covered by the heat insulating layer **45** and the waterproof layer **46**. Therefore, the cold energy stored in the ice storage device **41** can be prevented from being wasted by the external heat, and the external water will not penetrating into the tank **42**.

Moreover, the ice storage device **41** functioning as the auxiliary cooling device of the fourth example is configured to store the cold energy by freezing the cold storage medium stored therein only using the external cold energy. Therefore, in addition to the above-explained advantages, a layout of the cooling system for the datacenter can be altered flexibly and more easily in comparison with a cooling system for the datacenter using a conventional chiller unit adapted to cool the cooling medium electrically. For example, even in the case where the number of computer servers is increased and larger output of the cold energy is therefore required, the output of the ice storage device **41** can be easily increased by merely increasing the number of heat pipes **43**. In this case, the output of the ice storage device **41** can be increased without expanding an installation area of the ice storage device **41**. Alternatively, it is also possible to introduce additional ice storage devices **41** easily according to the required cold energy. Further, the conventional chiller unit used as the auxiliary cooling device in the conventional cooling system can be replaced easily by the cold storage device **41** of the present invention.

Next, here will be explained a fifth example of the present invention with reference to FIGS. **11** to **15**. The fifth example is another modified example of the auxiliary cooling device used in the third example. That is, a relation of connection of the elements constituting the cooling system is identical to those of the third and the fourth example shown in FIGS. **3** and **4**. Therefore, detailed explanation for the elements in common with the previously explained example is omitted by allotting common reference numerals.

The ice storage device **41** of the fifth example is preferably used as the auxiliary cooling device for the datacenter whose electrical power consumption is approximately 200 kWh. For this purpose, according to the fifth example, the ice storage device **41** is also buried in the ground, and in order to insulate the ice storage device **41** more effectively from the external heat thereby retaining the cold energy therein more efficiently, the ice storage device **41** of the fifth example is further provided with a soil layer **52** covering the tank **42**.

As shown in FIG. **12**, the ice storage device **41** of the sixth example is also shaped into a cylindrical shape, and a soil layer **52** is formed around the ice storage device **41**. FIG. **13** is a sectional view showing a cross section of the ice storage device **41** shown in FIG. **12**. Specifically, as shown in FIG. **13**, a maintenance room **50** is formed around the tank **42** of the ice storage device **41**. The soil layer **52** is held by a bottomed cylindrical wooden support **53**. In order to retain the soil and the water in the soil layer **52**, the waterproof layer **46** is interposed between the soil layer **52** and the wooden support **53**. In order to radiate the heat in the soil layer **52**, according to the fifth example, a plurality of another heat pipes **54** is buried in the soil layer **52** substantially vertically at predetermined intervals. Specifically, a thermosiphon is also used as the heat pipe **54**, therefore, a direction of the heat pipe **54** is restricted to one direction by a thermal diode characteristics thereof. That is, the external heat will not enter into the soil layer **52** through the heat pipes **54**. As shown in FIG. **14**, an entrance **51** is formed in the maintenance room **50** so that a worker is allowed to enter into the maintenance room **50**. In addition, the soil layer **52** is formed around the maintenance room **50**, and underneath the maintenance room **50** and the tank **42**. Specifically, the soil layer **52** contains 5 to 20 percent of moisture, and a thickness thereof is approximately 1 meter. Further, according to the fifth example, the aforementioned heat insulating layer **45** is formed around the wooden support **53** and underneath the bottom of the wooden support **53**. Additionally, as shown in FIG. **14**, the ice storage device **41** is covered with a shield **57**.

As shown in FIG. **15**, a portion of the heat pipe **54** buried in the soil layer **52** serves as an evaporating portion **54***a*, and other end portion of the heat pipe **54** is exposed to outside of the soil layer **52** to be contacted with the atmosphere serves as a condensing portion **54***b*. In order to radiate the heat of the soil layer **52** to the atmosphere from the condensing portion **54***b*, a plurality of fins **55** are arranged on the condensing portion **54***b*. Remaining structures of the heat pipe **54** are identical to those of the aforementioned heat pipe **43**. Therefore, a detailed explanation for the structure and function of the heat pipe **54** in common with those of the heat pipe **43** will be omitted. However, in order to prevent a corrosion of the heat pipe **54**, the heat pipe **54** may be made of corrosive-resistant material such as stainless. In addition, in order to radiate the heat in the bottom part of the soil layer **52** to the atmosphere, as shown in FIG. **15**, the evaporating portion **54***a* of the heat pipe **54** is bent at a vicinity of the bottom of the maintenance room **50** toward the center of the tank **42**. Here, in order to gravitationally return the working fluid to the end of the evaporating portion **54***a*, the bent portion of evaporating portion **54***a* is preferably tilted at approximately 5 degrees.

In the fifth example, sand, loam and clay can be used as a material of the soil layer **52**, and moisture content of those materials are 2.5 to 10 percent, 10 to 17.5 percent, and 17.5 to 25 percent, respectively. Therefore, in case of forming the soil layer **52** mainly using sand, it is preferably to keep the moisture content of the soil layer **52** within a range of 2.5 to 10 percent. Consequently, the soil layer **52** can be frozen and strength of the soil layer **52** can be enhanced by radiating the heat thereof to the atmosphere through the heat pipes **54**. Likewise, in case of forming the soil layer **52** using loam or clay, the moisture content thereof are preferably kept to the above-mentioned ranges respectively.

Next, here will be explained a function of the ice storage device **41** according to the fifth example. As in the previously explained examples, in case the temperature of the cold storage medium in the ice storage device **41** becomes higher than the external temperature, and the external temperature becomes lower than a predetermined temperature, the working fluid in the evaporating portion **43***a* of the heat pipe **43** is vaporized by the heat of the cold storage medium stored in the tank **42**, and the heat of the cold storage medium is transported to the condensing portion **43***b* in the form of the latent heat of the working fluid. The heat of the cold storage medium thus transported to the condensing portion **43***b* is radiated to the atmosphere through the fins **44**, and the condensed working fluid is returned gravitationally to the evaporating portion **43***a*. As a result, the cold storage medium in the tank **42** is cooled. In this situation, in case the external temperature further drops to below freezing point, the cooling medium in the ice storage device **41** is frozen by the same principle explained in the fourth example.

Likewise, in case the temperature of the soil layer **52** becomes higher than the external temperature, and the external temperature becomes lower than a predetermined operating temperature of the heat pipe **54**, the working fluid in the evaporating portion **54***a* of the heat pipe **54** is vaporized by the heat of the soil layer **52**, and the heat of the soil layer **52** is transported to the condensing portion **54***b* by the vaporized working fluid in the form of the latent heat. The heat of the soil layer **52** thus transported to the condensing portion **54***b* is radiated to the atmosphere through the fins **55**. Therefore, working fluid is condensed again in the condensing portion **54***b*, and returned gravitationally to the evaporating portion **54***a*. As a result, the soil layer **52** is cooled to store the cold energy therein. Also, in case the external temperature further drops to below the freezing point, the soil layer **52** is further cooled and frozen. As a result, the soil layer **52** becomes a permafrost layer. Conversely, since the thermosiphon is used as the heat pipe **54**, the heat pipe **54** will not transport the heat in case the temperature of the soil layer **52** becomes lower than the external temperature, and the external temperature becomes higher than a predetermined temperature.

Thus, the ice storage device **41** of the fifth example is further provided with the soil layer **52** having approximately 1 meter thickness, and the plurality of heat pipes **54** are buried therein. In addition, the soil layer **52** is covered by the heat insulating layer **45**, and the ice storage device **41** is installed in a cold region where a freezing index is higher than 400 degree C.·day. Therefore, in addition to the advantages achieved by the ice storage device **41** according to the third and the fourth examples, according to the fifth example, the soil layer **52** frozen by the heat pipes **54** can be kept to be frozen throughout the year. That is, the cold energy stored in the tank **42** by freezing the cold storage medium held therein can also be retained throughout the year by the soil layer **52** as a permafrost layer. The cold energy thus stored in the ice storage device **41** can be used to cool the datacenter **1** anytime when the chiller unit **11** is in trouble.

Next, here will be explained a modified example of the ice storage device **41** of the fifth example with reference to FIGS. **16** to **18**. The modified ice storage device **41** of the fifth example is to be used as the auxiliary cooling device for the datacenter whose electrical power consumption is smaller than 200 kWh. Therefore, according to the modified example of the fifth example, the tank **42** is relatively smaller than that used in the previously explained ice storage device **41**, and as shown in FIG. **16**, the ice storage device **41** is covered with a shield **57**. In addition, a U-shaped heat exchanging tube **56** is used instead of the coil-shaped heat exchanging tube **49**.

Specifically, as shown in FIG. **16**, most of the modified ice storage device **41** of the fifth example is buried in the ground, and the portion of the ice storage device **41** thus buried is covered with the shield **57**. A clearance between the soil layer **52** and the shield **57** is filled with another soil. An upper portion of the ice storage device **41** exposed above the ground level is covered with a lid **58**. In order to insulate the portion of the ice storage device thus exposed, the lid **58** is preferably made of heat insulating material such as concrete. The heat exchanging tube **56** is a hollow tube made of heat conductive material such as copper, copper alloy, aluminum, aluminum alloy and so on, and the liquid phase cooling medium flowing from the cold plate **9** flows therethrough. According to the modified example of the fifth example, the heat exchanging tube **56** thus structured is bent into U-shape, and arranged in the vicinity of the evaporating portion **54***a* of the heat pipe **54**. Therefore, the heat of the liquid phase cooling medium flowing through the heat exchanging tube **56** is drawn by the cold storage medium in the tank **42**.

In case of using the ice storage device **41** in the datacenter whose electrical power consumption is larger than 200 kWh, thereby requiring larger output of the ice storage device **41**, a capacity of the ice storage device **41** can be increased easily by merely combining a plurality of the ice storage devices **41** to form a larger auxiliary cooling system having a required capacity. An example of combining three ice storage devices **41** in the shield **57** is shown in FIG. **17**, and FIG. **18** is a cross sectional view thereof. Although not especially shown in FIGS. **17** and **18**, both of the coil shaped heat exchanging tube **49** and the U-shaped heat exchanging tube **56** can be used in this example.

As shown in FIG. **17**, each of the three ice storage device **41** is formed into a cuboid shape, and the plurality of heat pipes **43** are erected in the ice storage device **41**. In this example, each of the ice storage devices **41** is covered with the heat insulating layer **45** and the waterproof layer **46**. The ice storage devices **41** thus unified is enclosed entirely by the soil layer **52**. As described, a thickness of the soil layer **52** is preferably 1 meter, and the plurality of heat pipes **54** are erected in the soil layer **52**. However, in case of combining the plurality of ice storage devices **41** in this manner, a thickness of a soil layer **52** between the adjoining ice storage devices **41** can be reduced to be smaller than 1 meter.

Thus, the capacity of the ice storage device **41** can be increased easily by merely combining a plurality of the ice storage devices **41**. Therefore, even in the case where a number of the computer servers is increased and larger output of the auxiliary cooling device **41** is required, the larger cold energy can be stored in the auxiliary cooling device **41** by increasing the number of the ice storage device **41** without introducing additional air conditioners and chiller units. In addition, the cold energy of the frozen soil layer **52** can also be utilized to cool the datacenter **1** by merely arranging the coil shaped heat exchanging tube **49** or the U-shaped heat exchanging tube **56** in the soil layer **52**.

Next, an assist heat pipe according to the sixth example of the present invention will be explained with reference to FIG. **19**. In the example shown in FIG. **19**, a plurality of server racks **3** housing a plurality of computer servers therein are installed in the housing of the datacenter **1**, and the housing **2** is provided with an air conditioner **4** for the purpose of cooling the computer servers by lowering a temperature in the housing **2** raised by the electronic components of the servers. In addition, in order to assist the air conditioner **4** by radiating the heat in the housing **2** to the atmosphere, the heat pipe **5** is arranged in the housing **2** above the server rack **3** in the direction of gravitational force.

Specifically, as the heat pipes used in the above-explained examples, the assist heat pipe **5** is also a thermosiphon comprising an evacuated hollow container, and volatile and condensable working fluid contained in the container air-tightly. In order to exchange internal heat and external cold energy efficiently, the container of the assist heat pipe **5** is also made of material having good heat conductivity such as copper. In addition, the working fluid of the assist heat pipe **5** is selected from water, ammonia and hydrochlorofluorocarbon and so on depending on a condition of temperature.

Specifically, according to the example shown in FIG. **19**, one of end portions of the assist heat pipe **5** extending parallel to the ceiling of the housing **2** above the server rack **3** serves as the evaporating portion **5***a* at which the working fluid is heated to be vaporized by the internal heat of the housing **2**. The assist heat pipe **5** is bent at a substantially right angle while penetrating through the ceiling to be exposed to the outside of the housing **2**. The other end portion of the assist heat pipe **5** thus exposed to the outside of the housing **2** to be contacted with the external air serves as the condensing portion **5***b* at which the vaporized working fluid is condensed by radiating the heat thereof to the atmosphere. In addition, a plurality of fins **6** for radiating and receiving the heat is arranged on both of the evaporating portion **5***a* and the condensing portion **5***b*. Here, the fins **6** are also formed of heat conductive material.

Therefore, in case the internal temperature of the housing **2** is raised by the electronic components to be higher than the external temperature, or in case the external temperature becomes lower than the internal temperature of the housing **2**, the working fluid is vaporized in the evaporating portion **5***a* of the assist heat pipe **5**. The vapor of the working fluid rises toward the condensing portion **5***b* where the temperature and the pressure are lower than those in the evaporating portion **5***a*, and the internal heat of the housing **2** thus transported to the condensing portion **5***b* by the vaporized working fluid is then radiated to the atmosphere thorough the fins **6**. As a result, the vaporized working fluid is condensed again in the condensing portion **5***b* and returned gravitationally to the evaporating portion **5***a*. Thus, a thermal diode characteristic of the assist heat pipe **5** also ensures transport of the heat unilaterally from evaporating portion **5***a* toward the condensing portion **5***b* thereby radiating the internal heat of the housing **2** unilaterally to the outside of the housing **2**. For this reason, the external heat will not enter into the housing **2** through the assist heat pipe **5**.

Thus, according to the sixth example, the inner space of the housing **2** is cooled by transporting the internal heat of the housing **2** outside of the housing **2** through the assist heat pipe **5** under the condition in which the internal temperature of the housing **2** is higher than the external temperature. Therefore, a burden on the air conditioner **4** can be lightened so that an operating time of the air conditioner **4** can be shortened. As a result, an electric consumption of the air conditioner **4** is reduced so that CO_2 emission can be reduced. In addition, since the external heat will not enter into the housing **2** thorough the assist heat pipe **5**, the internal temperature of the container **2** can be prevented from being raised by the external heat.

Although the above exemplary embodiments of the present invention have been described, it will be understood by those skilled in the art that the present invention should not be limited to the described exemplary embodiments, but that various changes and modifications can be made within the spirit and scope of the present invention.

What is claimed is:

1. A cooling system for a data center, in which a plurality of servers having exothermic electronic components is installed in a housing, comprising:

a circuit, in which a first cooling medium is circulated therethrough;

a main cooling device, which is connected with the electronic components through the circuit, and to which the first cooling medium heated by drawing heat from the electronic components is returned; and

an auxiliary cooling device, which is arranged on a return pipe of the circuit between the main cooling device and the electronic components to assist the main cooling device in cooling of the first cooling medium,

wherein the main cooling device comprises a compressor which compresses a second cooling medium by applying a pressure to the second cooling medium, a condenser which transports heat of the compressed second cooling medium to outside, thereby condensing the second cooling medium, an expansion valve which adiabatically expands the condensed second cooling medium, and an evaporator which removes the heat from the first cooling medium by the second cooling medium that is expanded and thereby having a temperature which is lowered;

wherein the auxiliary cooling device is configured to cool the first cooling medium flowing back to the main cooling device by radiating the heat of the first cooling medium to the atmosphere, and comprises a tank which stores the first cooling medium therein, and a first plurality of heat pipes which are adapted to cool or freeze the first cooling medium by radiating the heat of the first cooling medium to the atmosphere;

wherein the tank comprises a plurality of flow channels formed as grooves between ribs on a bottom of the tank, and the first cooling medium flows unidirectionally through the flow channels;

wherein the plurality of heat pipes comprises thermosiphons, in which a volatile and condensable working fluid is encapsulated in an air-tight fashion;

wherein first end portions of the thermosiphons are immersed into the first cooling medium in the flow channels of the tank to serve as an evaporation portion, and second end portions of the thermosiphons are exposed to the atmosphere to serve as a condensing portion; and

wherein the first plurality of heat pipes are arranged such that the volatile and condensable working fluid drops only gravitationally to unidirectionally restrict direction of transport of the heat.

2. The cooling system for a data center according to claim **1**, further comprising:

a heat exchanger, which is arranged on the circuit between the electronic components and the main and auxiliary cooling devices to exchange the heat of the electronic components and cold energy of the first cooling medium.

3. The cooling system for a data center according to claim **1**, further comprising:

a cooling tower, which is connected with the main cooling device to radiate heat of the main cooling device to the atmosphere.

4. The cooling system for a data center according to claim **1**, further comprising:

a mixing tank.

5. The cooling system for a data center according to claim **4**, wherein:

the mixing tank is divided into a plurality of mixing chambers, and adjoining mixing chambers are connected by a through hole.

6. The cooling system for a data center according to claim **5**, further comprising:

a first switching valve, which switches a route for feeding the cooling medium from the mixing tank to the electronic component between a route from said one of the mixing chamber to the electronic component, and a route from said another one of the mixing chamber to the electronic component;

a first pump, which is arranged between the first switching valve and the electronic component to feed the cooling medium to the electronic component;

a second switching valve, which switches a route for feeding the cooling medium from the mixing tank to the main cooling device between a route from said one of the mixing chamber to the main cooling device, and a route from said another one of the mixing chamber to the main cooling device;

a second pump, which is arranged between the second switching valve and the main cooling device to feed the cooling medium to the main cooling device; and

a third pump, which is arranged on a route between said one of the mixing chamber and the auxiliary cooling device to feed the cooling medium in said one of the mixing chamber to the auxiliary cooling device.

7. The cooling system for a data center according to claim **1**, further comprising:

a first switching valve, which returns the cooling medium heated by heat of the electronic components selectively to the main cooling device and the auxiliary cooling device; and

a second switching valve, which supplies the cooling medium to the electronic component selectively from the main cooling device and the auxiliary cooling device.

8. The cooling system for a data center according to claim **7**, further comprising:

a first pump, which is arranged on the circuit connecting the electronic component and the heat exchanger to circulate the cooling medium therethrough;

a second pump, which is arranged on the circuit connecting the heat exchanger and the main cooling device to circulate the cooling medium therethrough; and a third pump, which is arranged on the circuit connecting the main cooling device and the cooling tower to circulate the cooling medium therethrough.

9. The cooling system for a data center according to claim **1**, wherein the auxiliary cooling device further comprises:

a heat insulating layer, which covers the tank to prevent the tank from being warmed by an external heat.

10. The cooling system for a data center according to claim **9**, wherein the heat insulating layer comprises:

an inner layer formed of an evacuated panel in which an internal pressure is reduced to be lower than an atmospheric pressure; and

an outer layer formed of heat insulating porous material.

11. The cooling system for a data center according to claim **9**, wherein the auxiliary cooling device further comprises:

a soil layer containing predetermined moisture and covering the tank; and

a second plurality of heat pipes which are buried in the soil layer at least partially to freeze the moisture in the soil layer by radiating the heat of the moisture unilaterally to the atmosphere, under the condition in which a temperature of the moisture in the soil layer is higher than an external temperature and the external temperature is lower than a predetermined temperature.

12. The cooling system for a data center according to claim **11**, wherein:

said second plurality of heat pipes comprise thermosiphons, in which a volatile and condensable working fluid is encapsulated air-tightly;

wherein one of end portions of the thermosiphons are buried in the soil layer to serve as an evaporating portion; and the other end portion of the thermosiphons are exposed to the atmosphere to serve as a condensing portion, and wherein the first plurality of heat pipes are arranged such that the condensed working fluid drops only gravitationally to unilaterally restrict the direction of transport of the heat.

13. The cooling system for a data center according to claim **11**, wherein:

a thickness of the soil layer is approximately 1 meter.

14. The cooling system for a data center according to claim **13**, wherein:

the material of the soil layer is selected from a group consisting of sand, loam and clay.

15. The cooling system for a data center according to claim **14**, wherein a moisture content of the soil layer is kept within a range of 2.5 to 10% when the soil layer is formed of sand, a moisture content of the soil layer is kept within a range of 10 to 17.5% when the soil layer is formed of loam, and a moisture content of the soil layer is kept within a range of 17.5 to 25% when the soil layer is formed of clay.

16. The cooling system for a data center according to claim **1**, wherein the auxiliary cooling device further comprises:

a cold storage medium, which is sealed in the tank to be frozen by external cold energy entering into the tank through the thermosiphon; and

a heat exchanging tube, which is arranged around the evaporating portion of the thermosiphon, and at which the cold energy of the frozen cold storage medium in the tank is transferred to the cooling medium flowing therethrough.

17. The cooling system for a data center according to claim **16**, wherein:

the heat exchanging tube includes a coil heat exchanger formed by winding a hollow tube around the evaporating portion of the thermosiphon.

18. The cooling system for a data center according to claim **17**, wherein:

the material of the heat exchanging tube is selected from the group consisting of copper, copper alloy, aluminum, aluminum alloy, and synthetic resin.

19. The cooling system for a data center according to claim **16**, wherein:

the heat exchanging tube includes a U-shaped heat exchanger formed by bending a hollow tube into U-shape and arranged in the vicinity of the evaporating portion of the thermosiphon.

20. The cooling system for a data center according to claim **1**, further comprising:

an air conditioner, which is arranged in the housing to control the temperature in the housing thereby cooling the server; and

an assist heat pipe, which transports heat in the housing unilaterally to the atmosphere thereby assisting the air conditioner; and

wherein the assist heat pipe includes a thermosiphon, in which a volatile and condensable working fluid is encapsulated air-tightly;

one of end portions of the thermosiphon is situated in the housing above the server in a direction of gravitational force, and the other end portion of the thermosiphon is exposed to the atmosphere; and,

wherein the assist heat pipe is arranged such that the condensed working fluid drops only gravitationally to unilaterally restrict the direction of transport of the heat.

21. The cooling system for a data center according to claim **1**, wherein the auxiliary cooling device is buried in the ground in a cold region where a freezing index is higher than 400 degree C.·day.

22. A process of cooling a data center, wherein the process comprises the steps of supplying the cooling medium heated by the electronic component, and the cooling medium cooled by the main cooling device or the auxiliary cooling device, to the mixing tank of the cooling system of claim **4** to regulate the temperature thereof; and

selectively supplying the cooling medium mixed in the mixing tank to the main cooling device and the auxiliary cooling device to be cooled, and also to the electronic component.

23. A process of cooling a data center, wherein the process comprises the steps of

supplying the cooling medium heated by the electronic component to one of the mixing chambers connected with the electronic component; and

supplying the cooling medium cooled by the main cooling device or the auxiliary cooling device to another one of the mixing chambers of claim **5** connected with the main cooling device and the auxiliary cooling device; and

gradually mixing the cooling medium heated by the electronic component, and the cooling medium cooled by the main cooling device or the auxiliary cooling device, in the mixing tank while flowing across the mixing chambers.

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