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(54) **ACTIVE MAGNETIC REFRIGERATOR**

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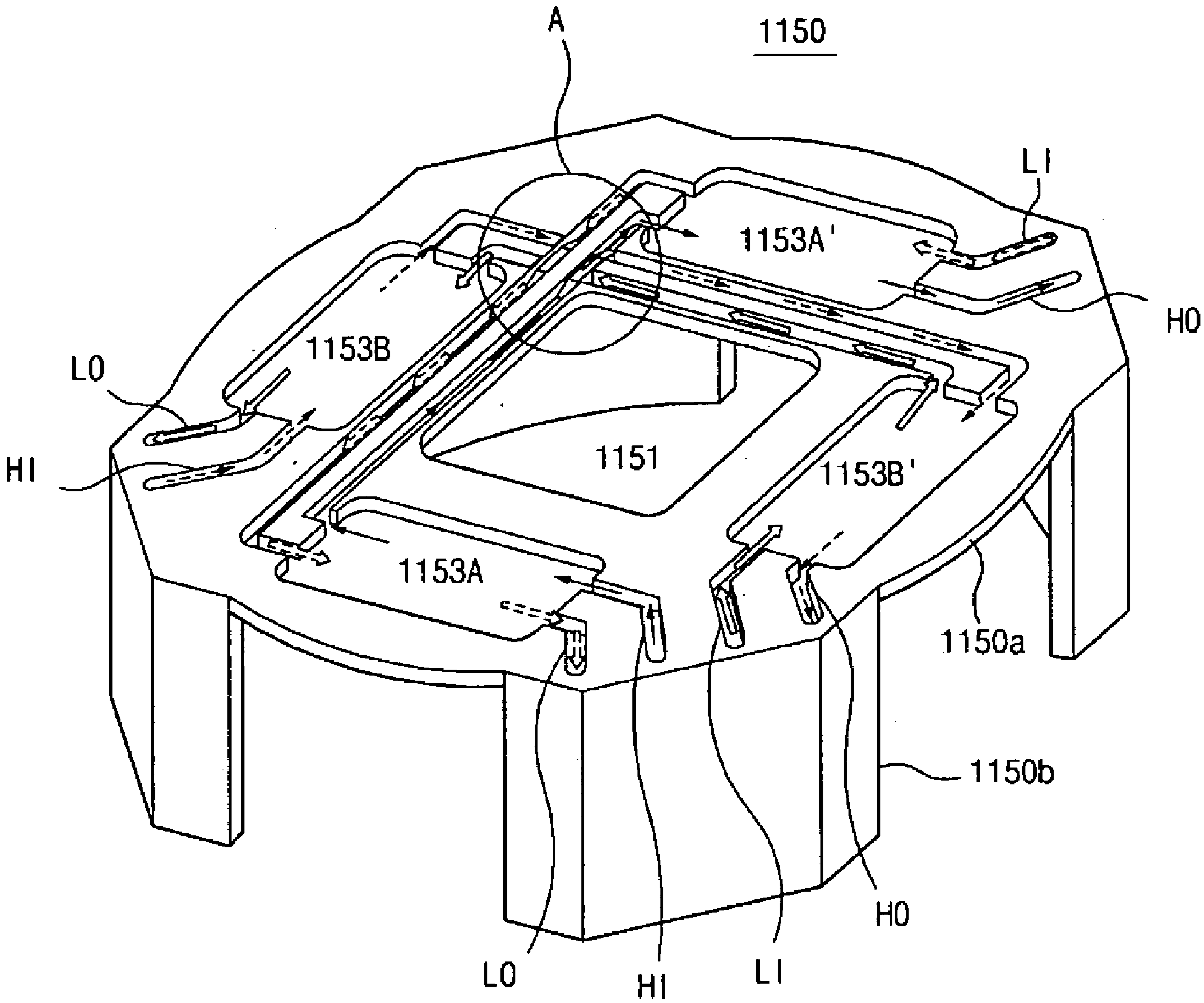
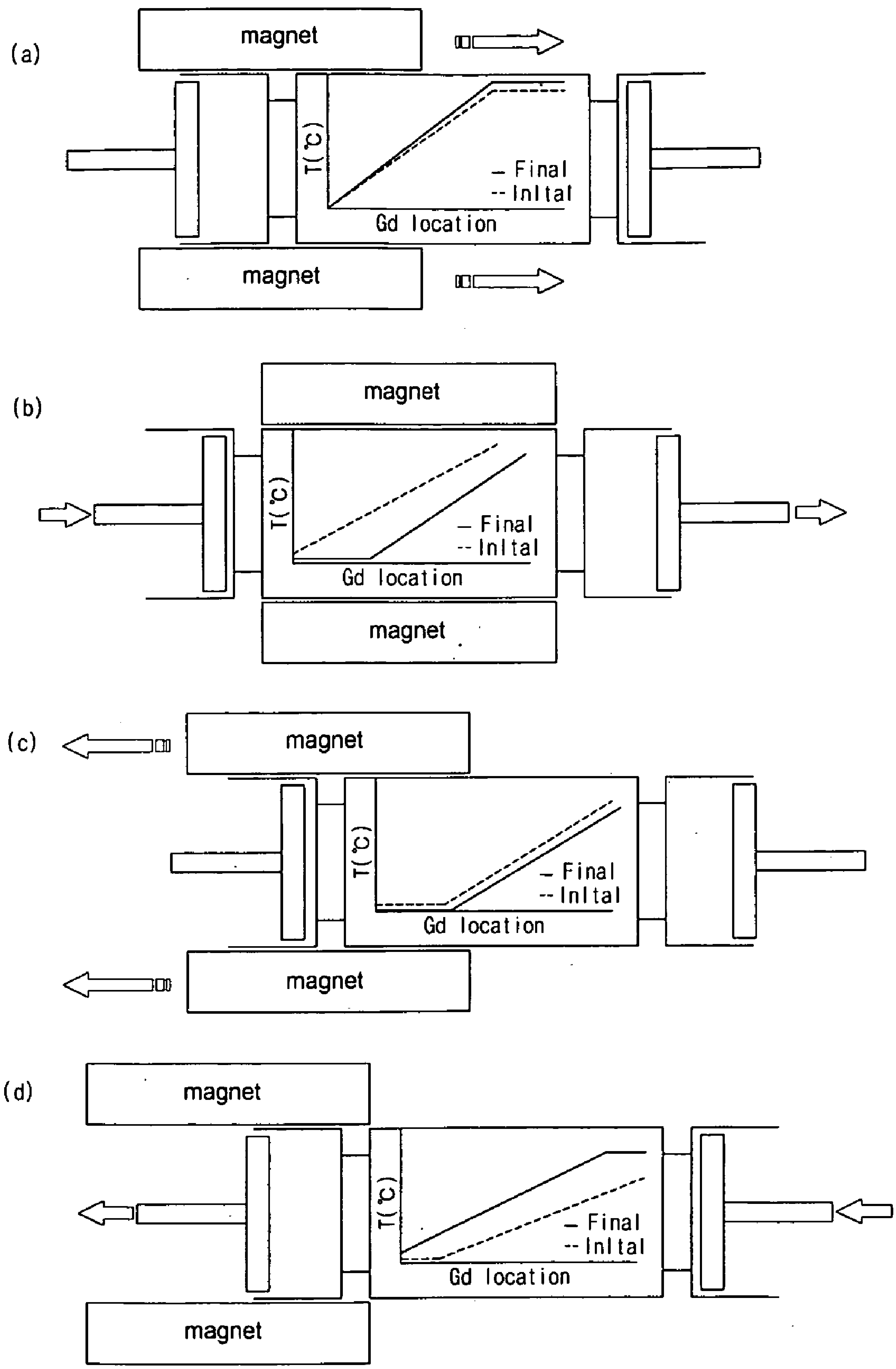
(52) **U.S. Cl.** **62/3.1**

(57) **ABSTRACT**

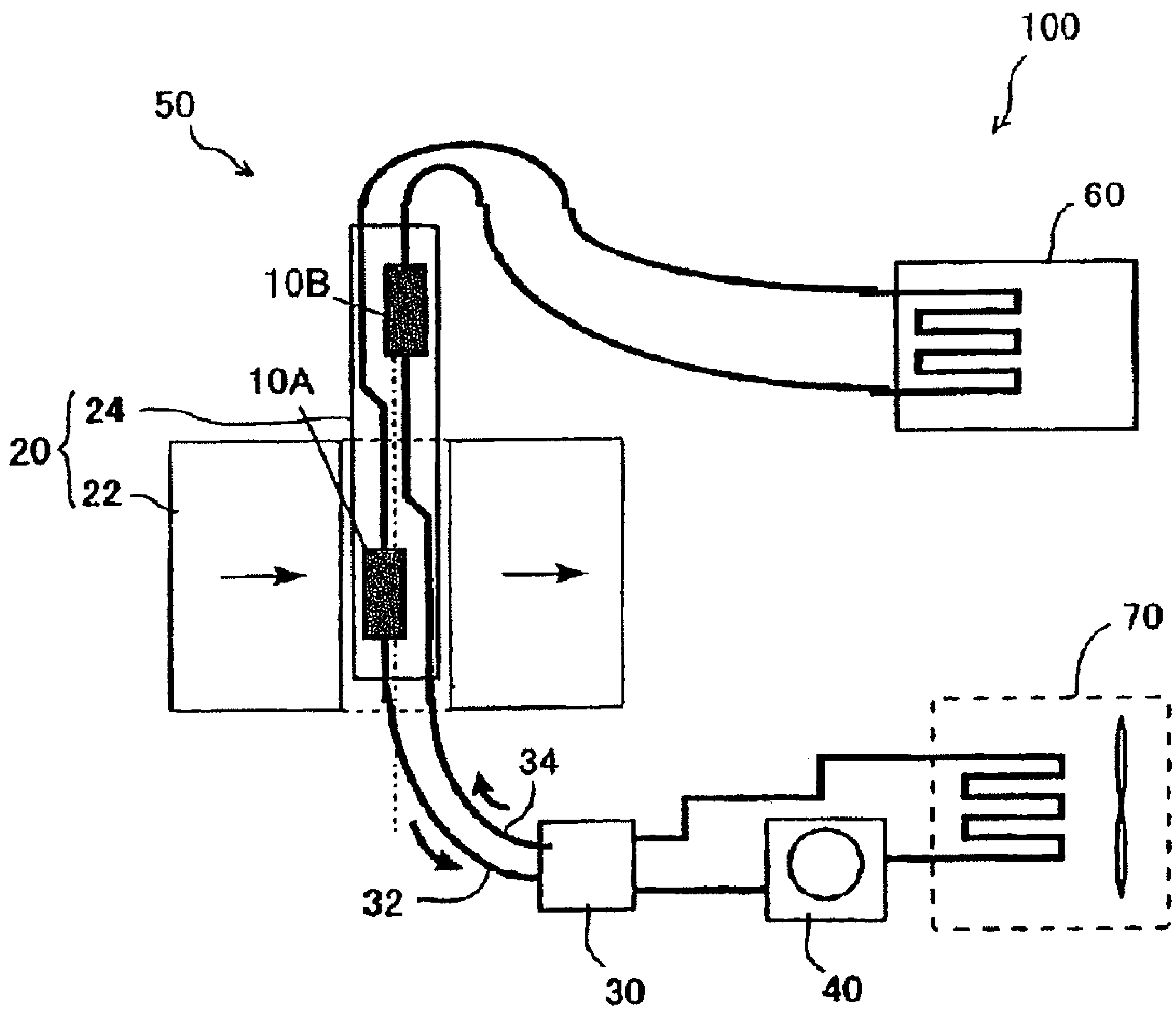
An active magnetic refrigerator includes separated hot and cold heat exchange units wherein a heat transfer fluid that exchanges a heat with a magnetic heat exchange unit having the magnetocaloric material pieces arranged to have a gap therebetween separately circulates through a solenoid valve.



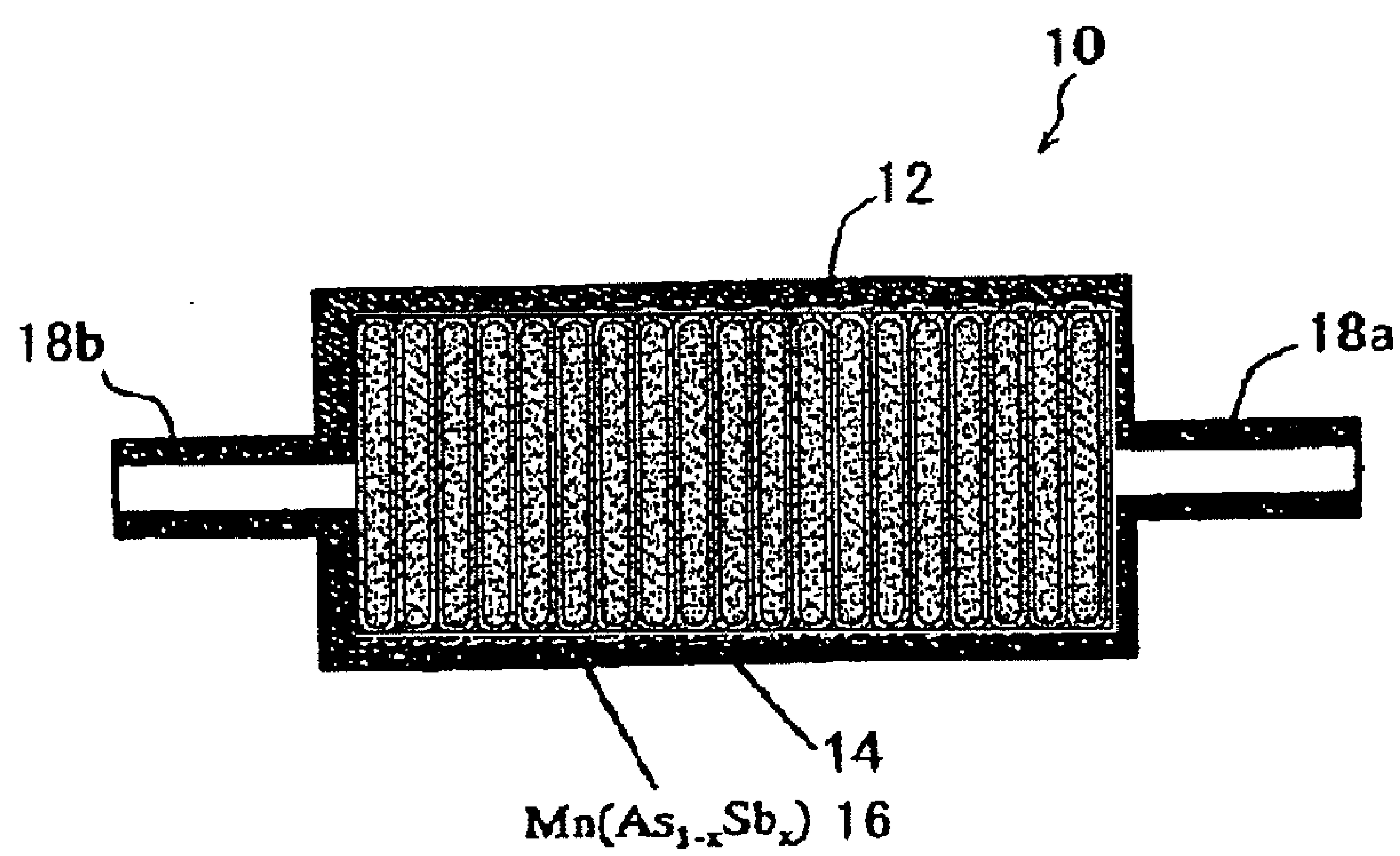
【FIGURE 1】


(a)
magnet
magnet
T(℃)
— Final
-- Inital
Gd location
(b)
magnet
magnet
T(℃)
— Final
-- Inital
Gd location
(c)
magnet
magnet
T(℃)
— Final
-- Inital
Gd location
(d)
magnet
magnet
T(℃)
— Final
-- Inital
Gd location

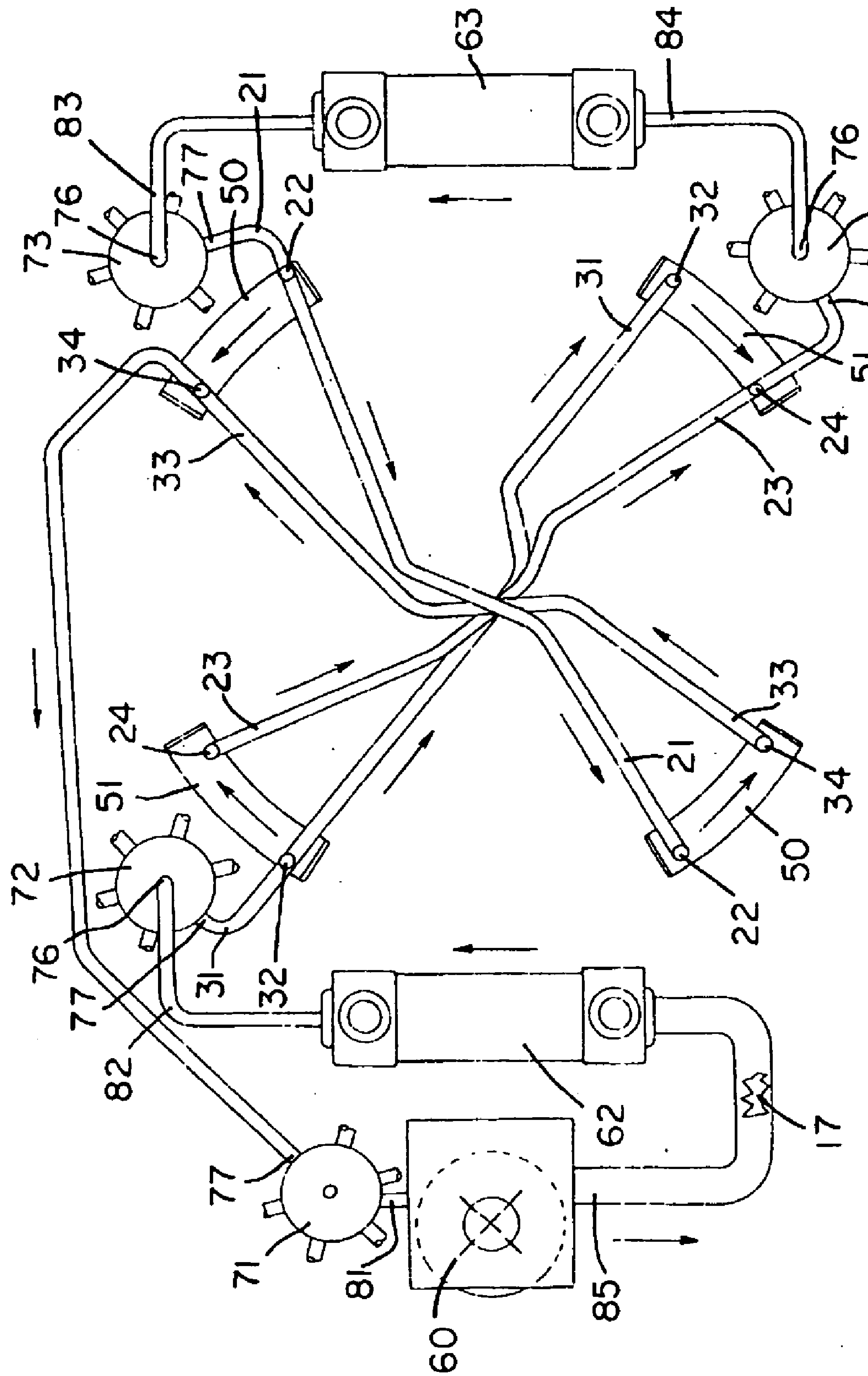
【FIGURE 2】



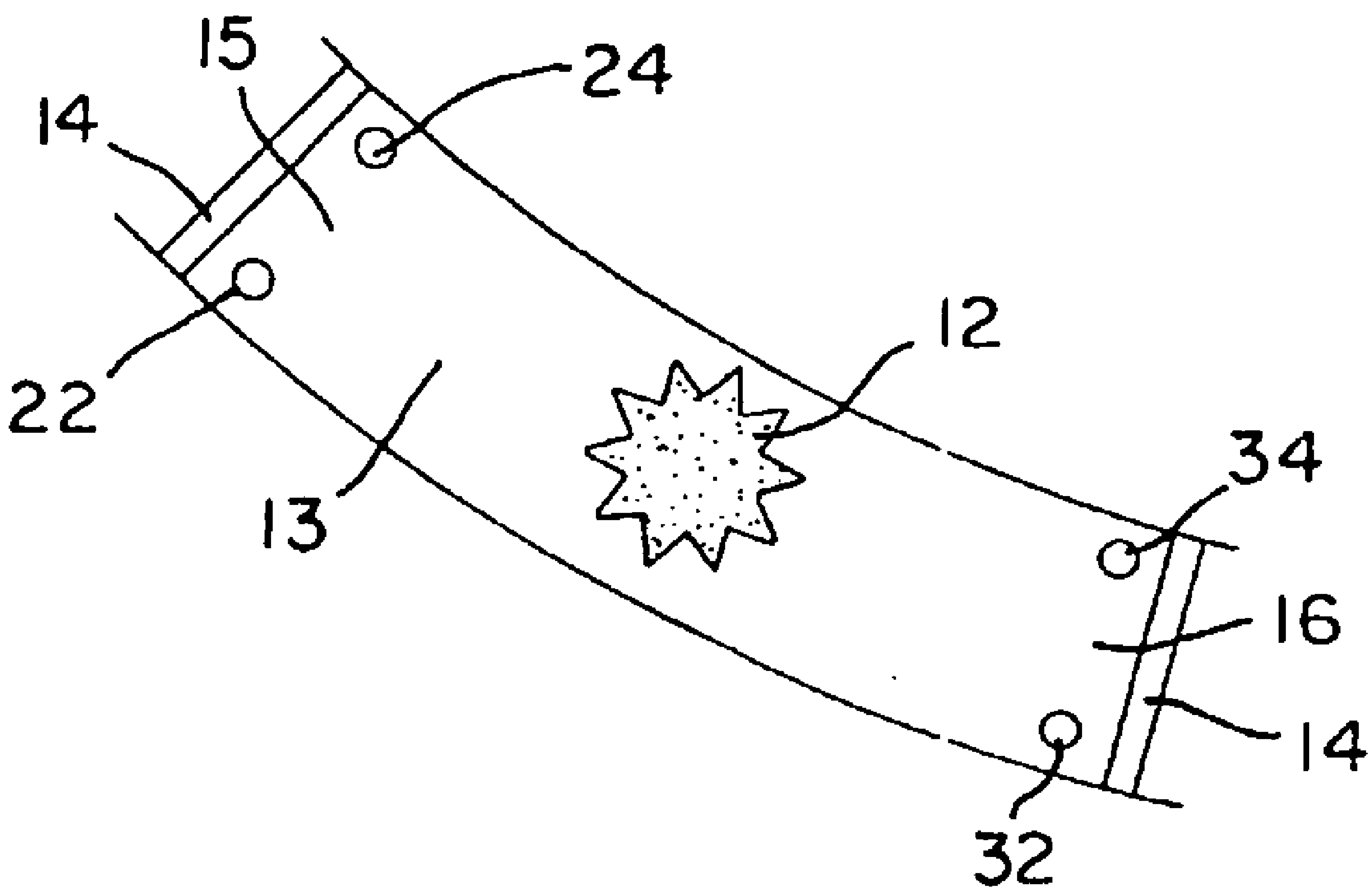
【FIGURE 3】



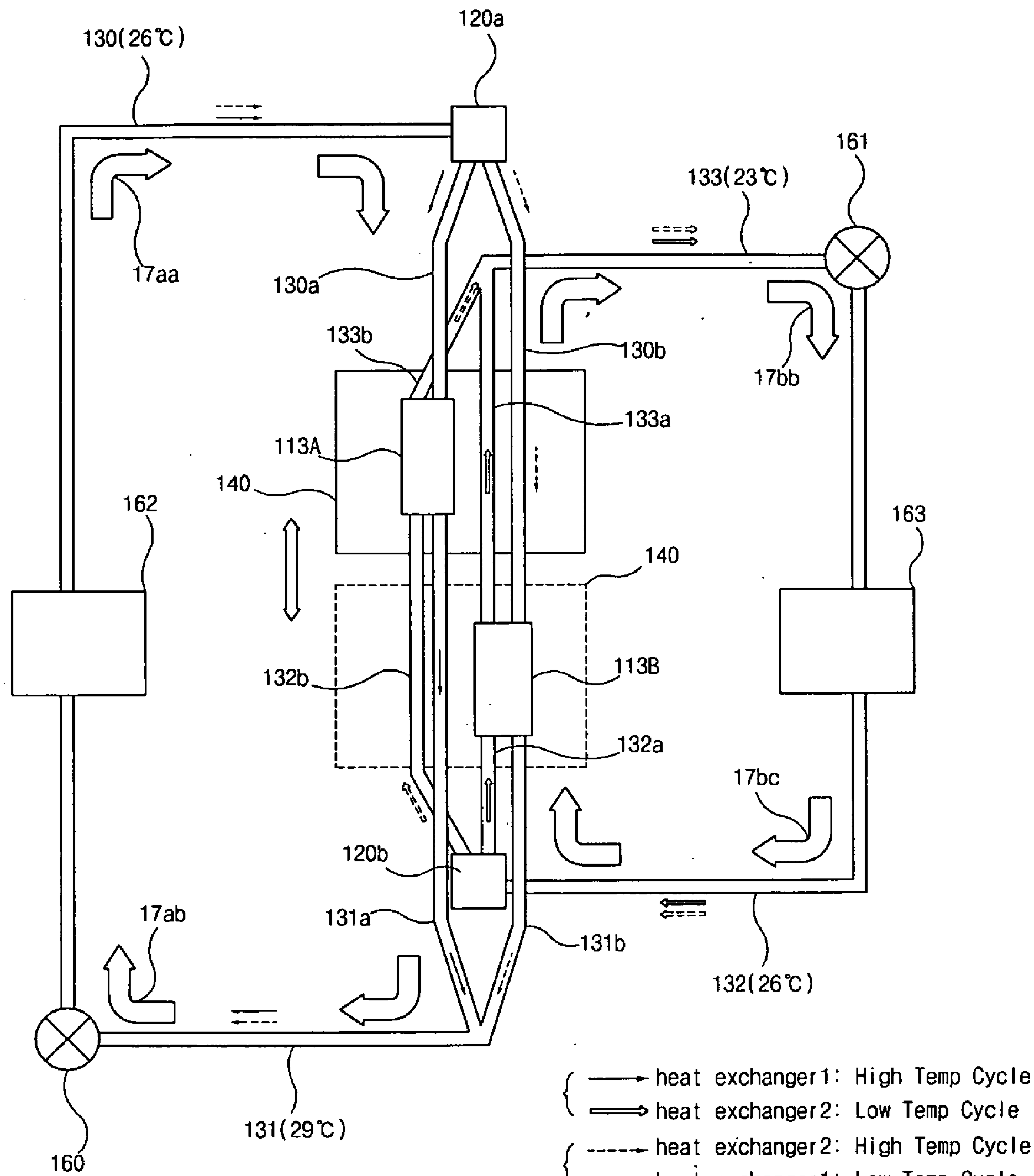
【FIGURE 4】


63
84
83
21
77
50
22
76
73
32
74
31
34
51
24
33
23
72
82
62
17
71
81
60
85

【FIGURE 5】

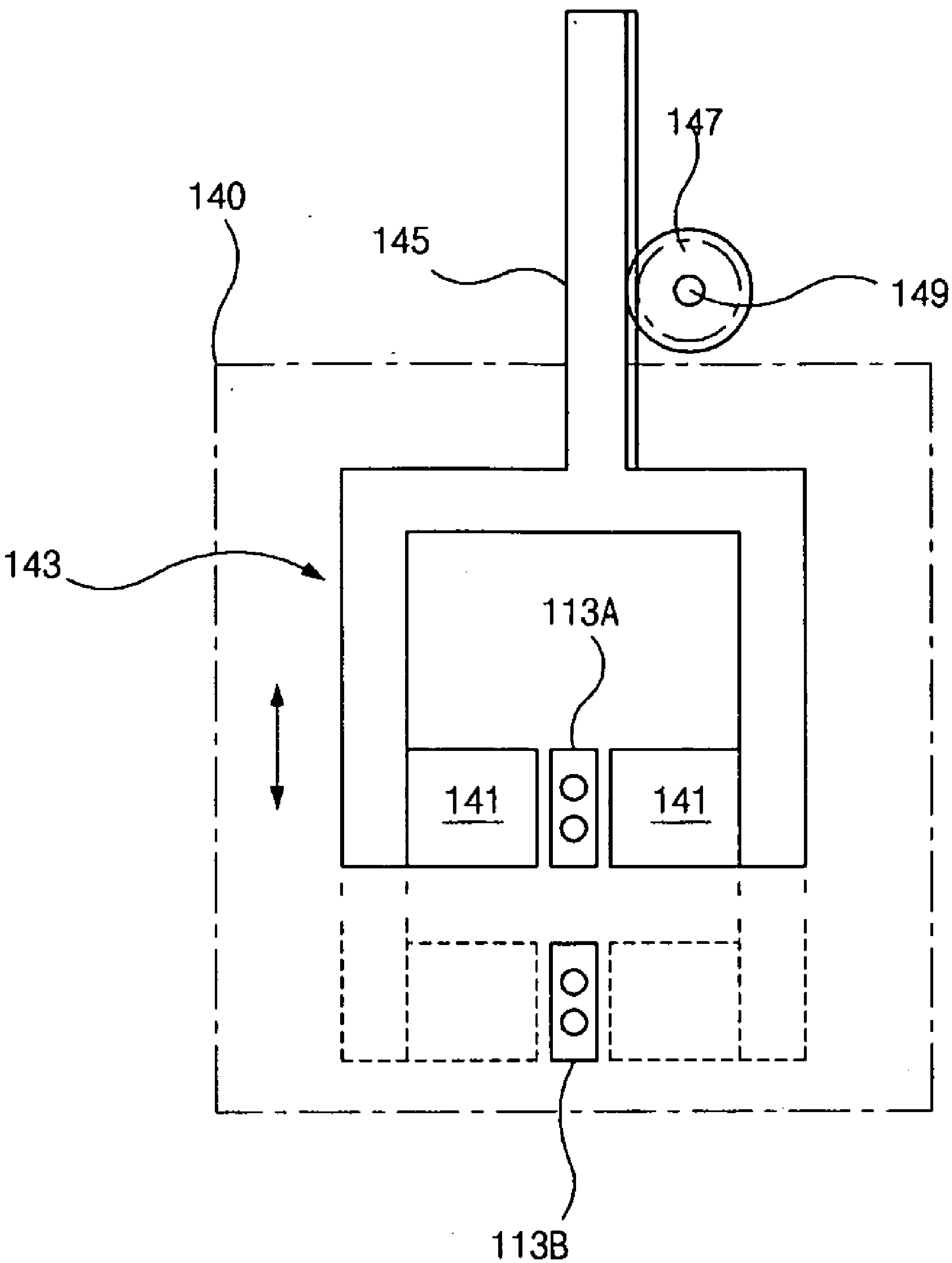


【FIGURE 6】

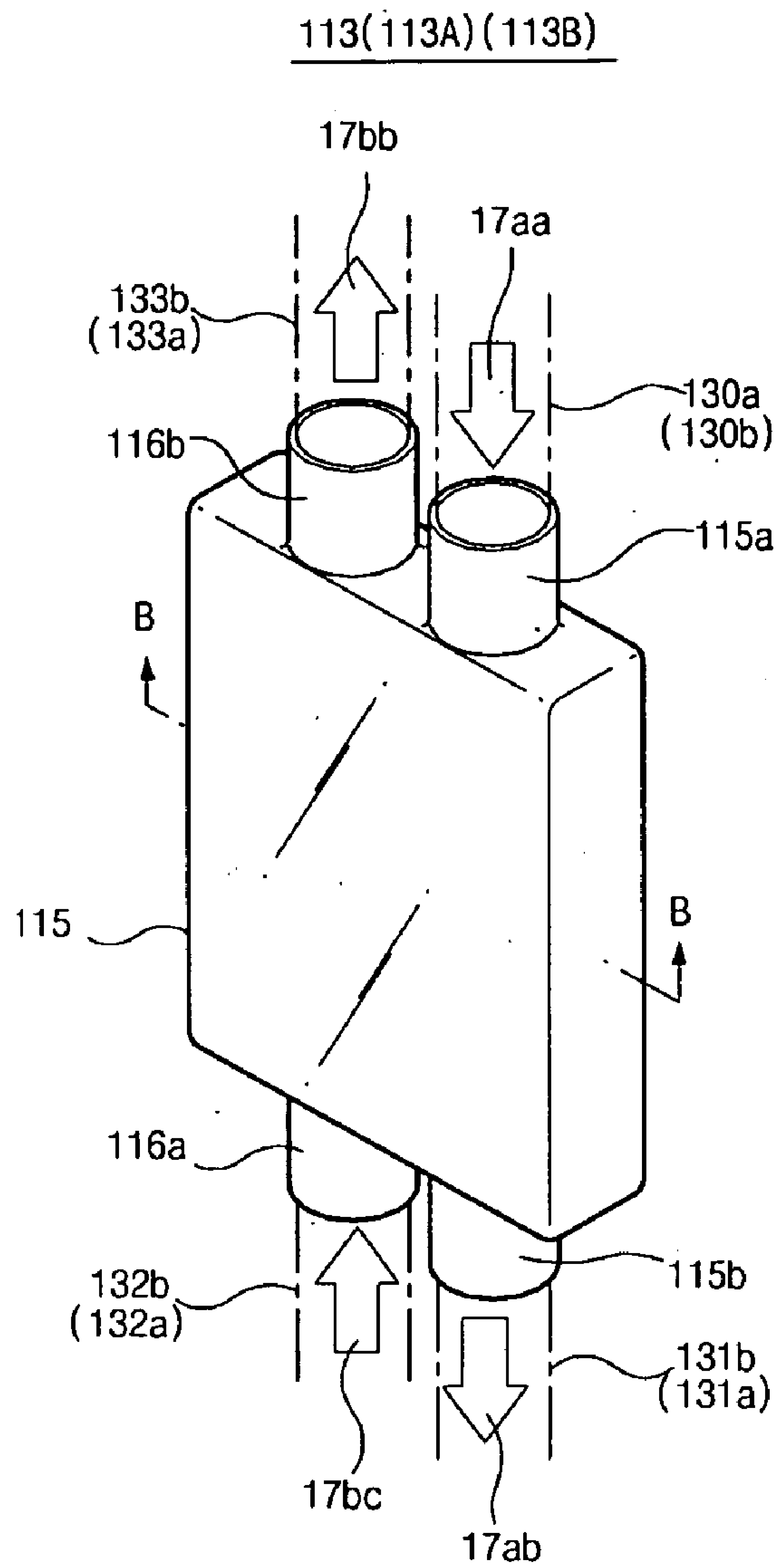


130(26℃)
120a
161
133(23℃)
17aa
130a
130b
17bb
133b
133a
113A
140
162
163
140
132b
113B
132a
17bc
120b
17ab
131a
131b
132(26℃)
131(29℃)
160
heat exchanger1: High Temp Cycle
heat exchanger2: Low Temp Cycle
heat exchanger2: High Temp Cycle
heat exchanger1: Low Temp Cycle

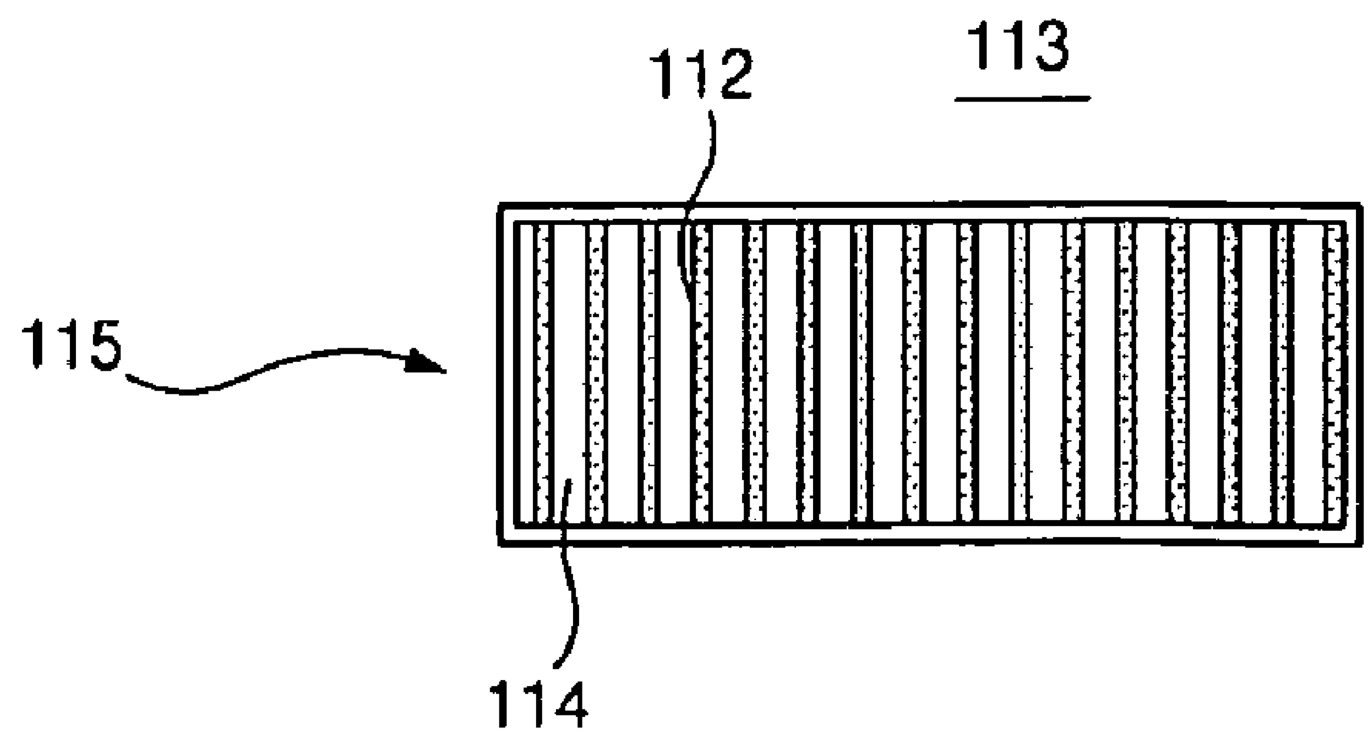
【FIGURE 7】



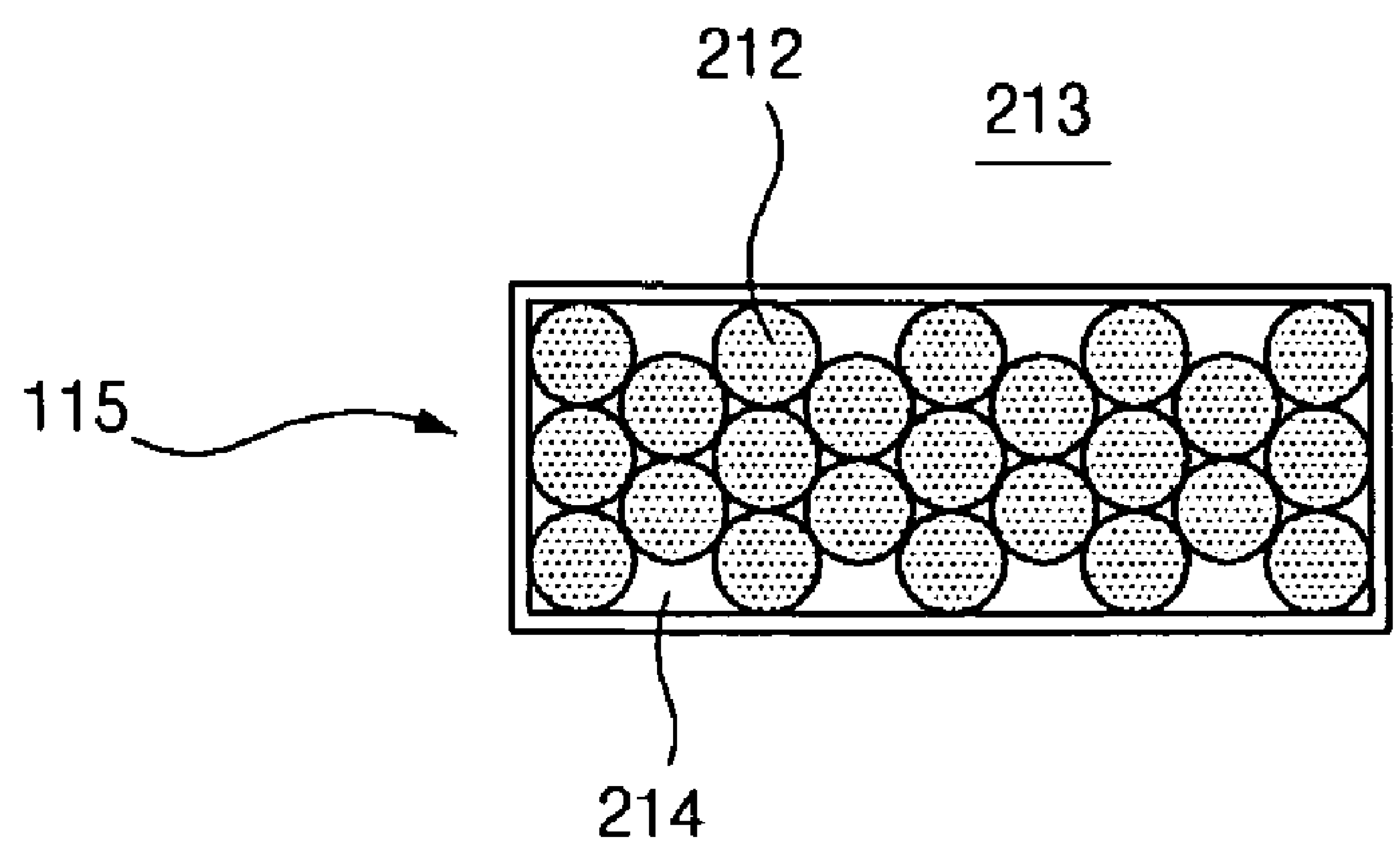
【FIGURE 8】



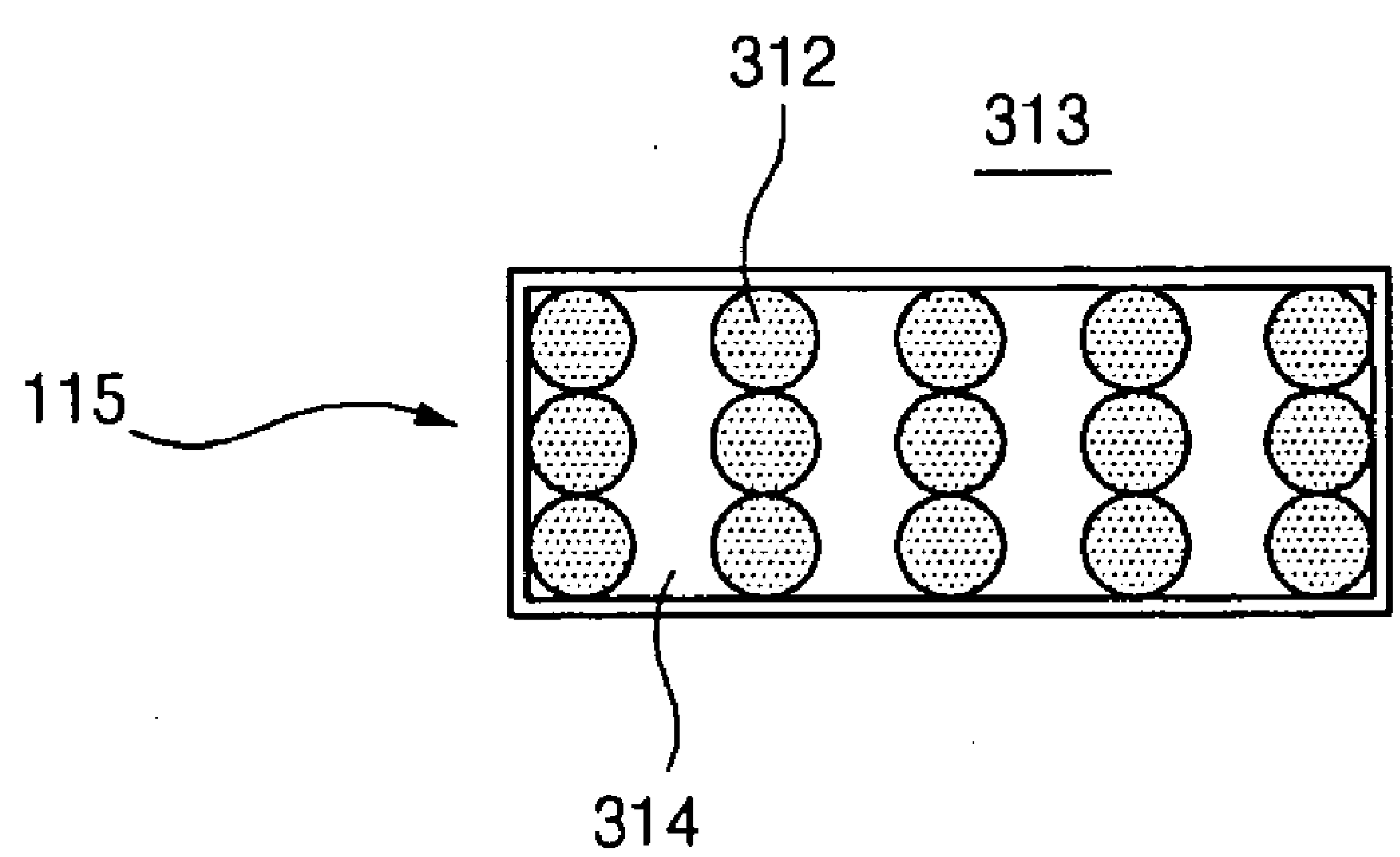
【FIGURE 9】



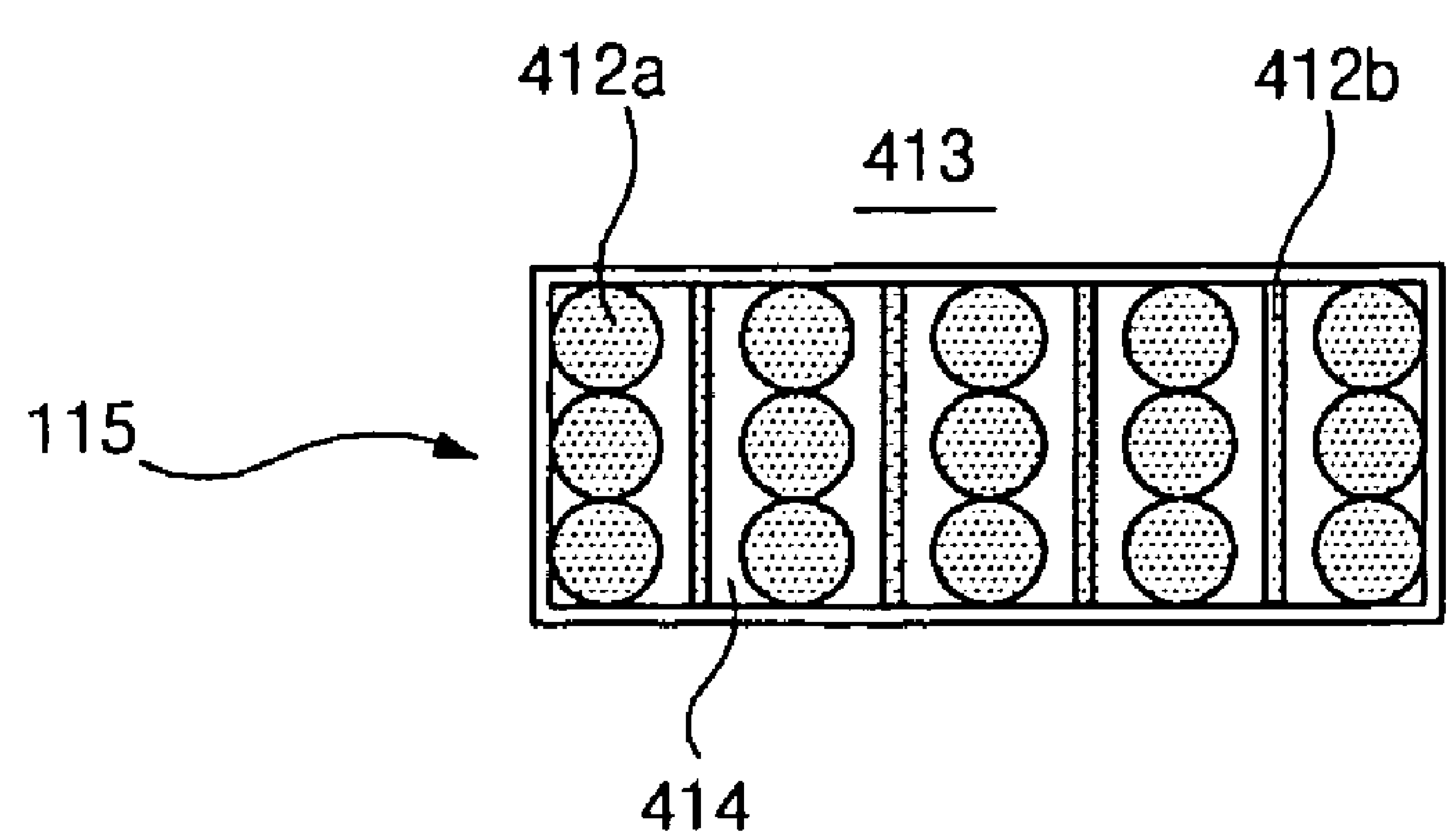
【FIGURE 10】



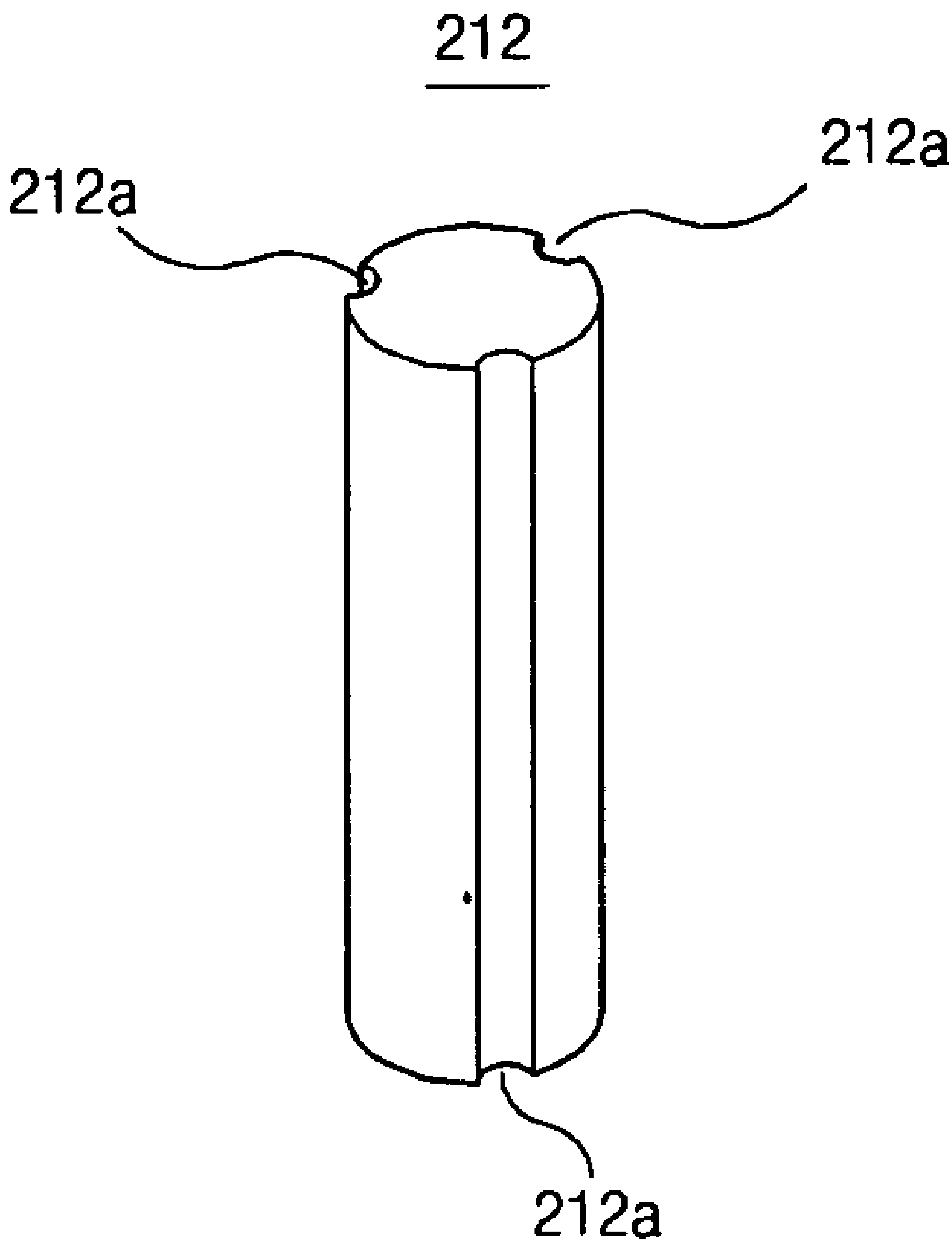
【FIGURE 11】



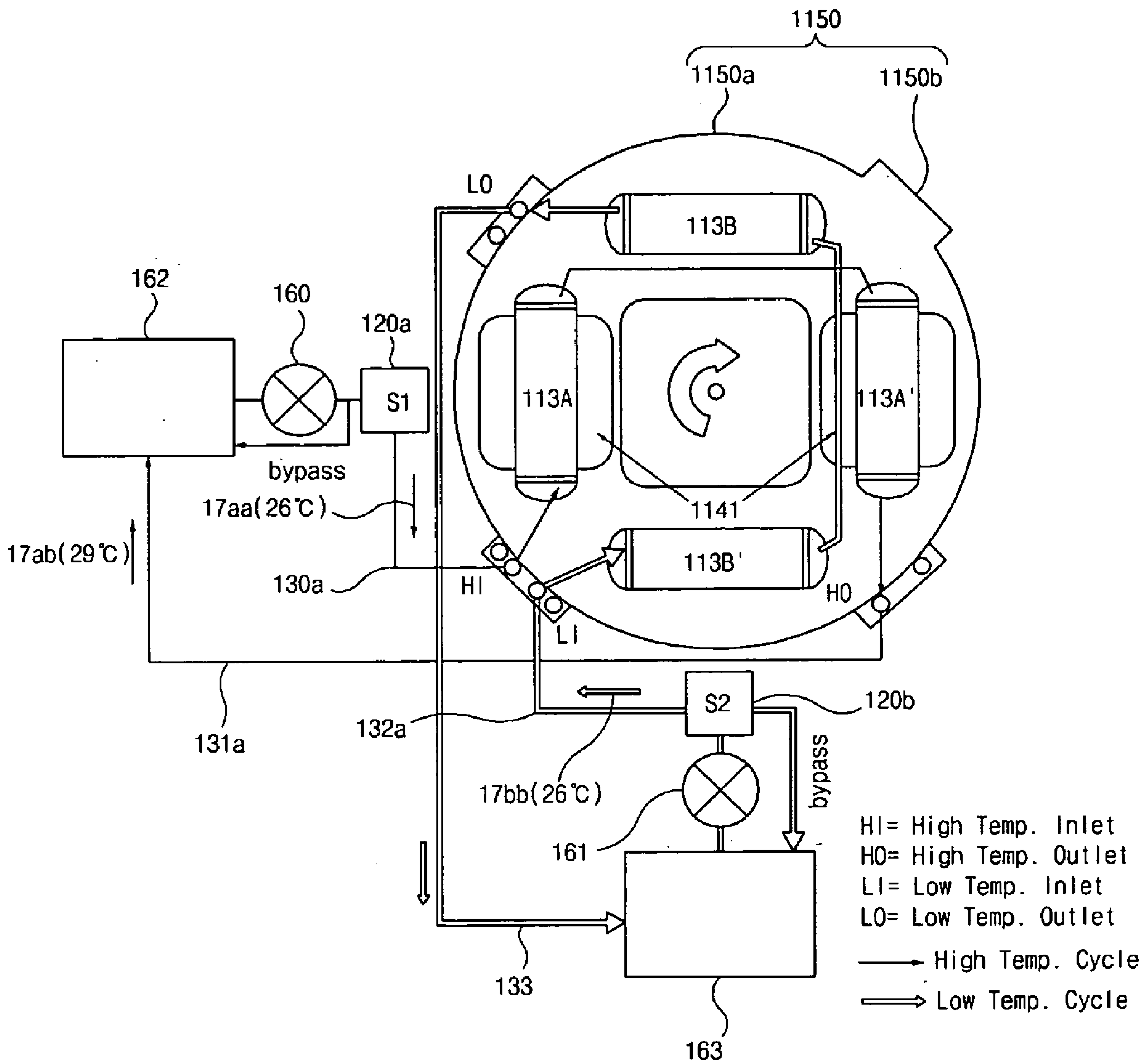
【FIGURE 12】



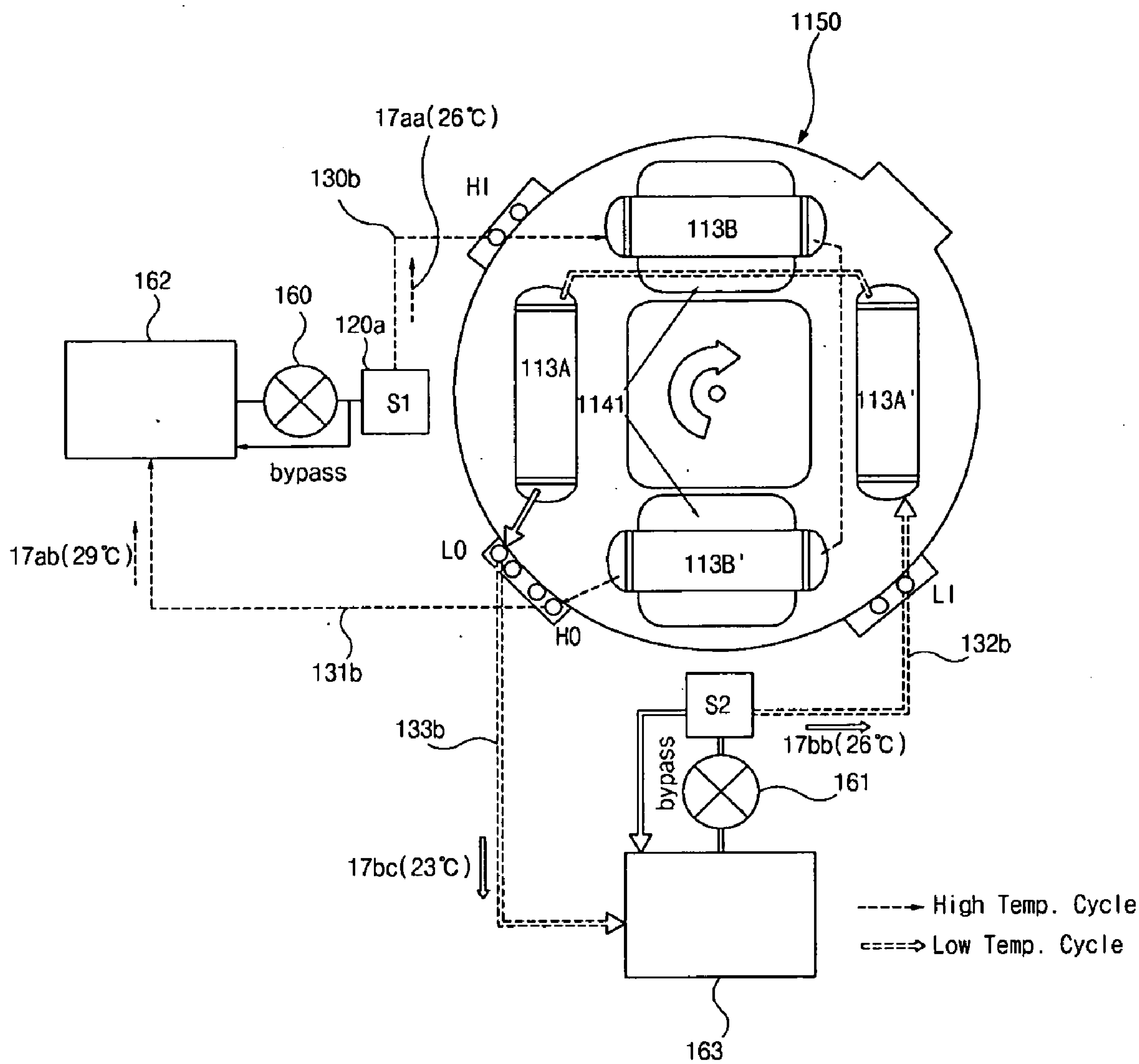
【FIGURE 13】



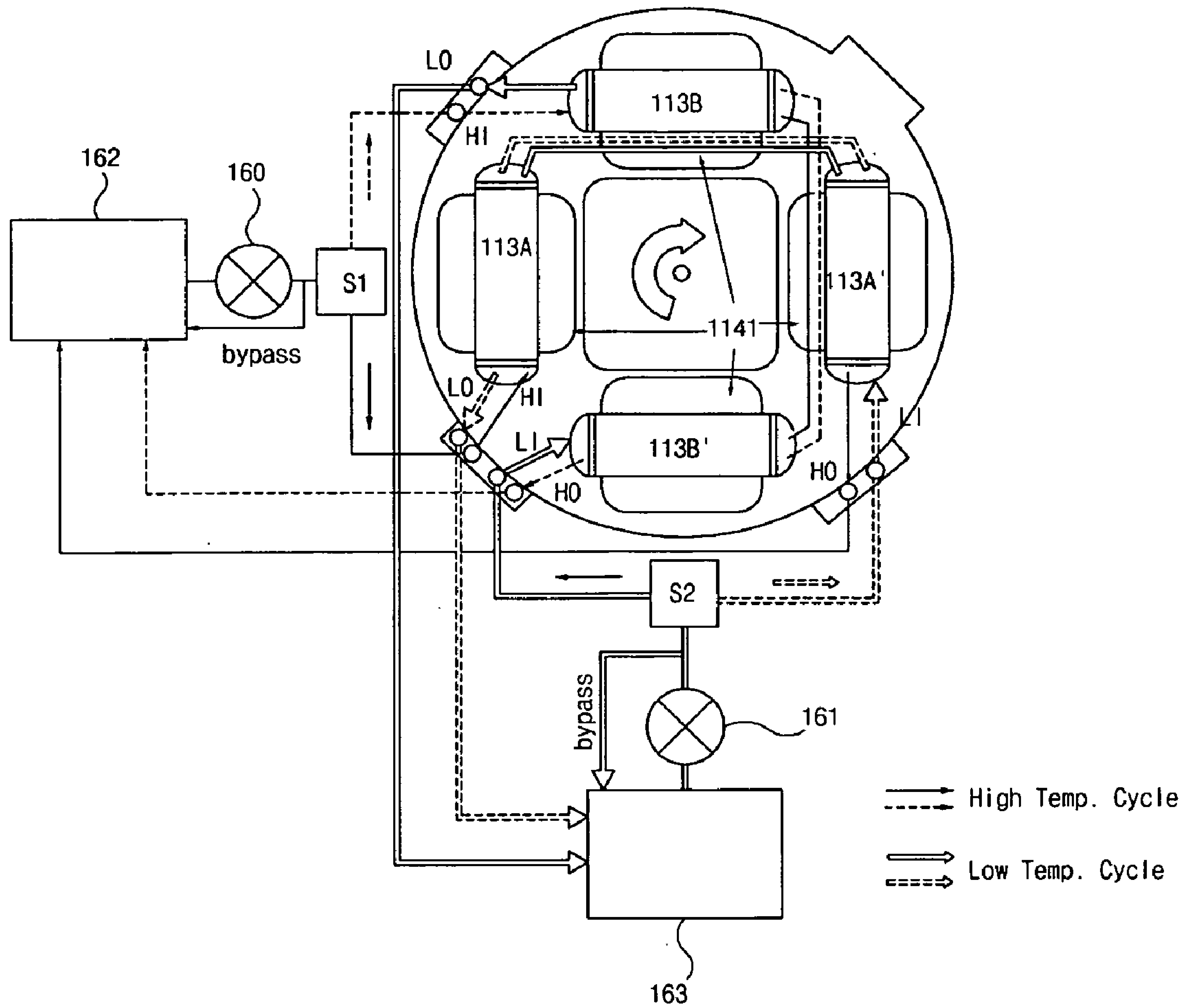
【FIGURE 14】


1150
1150a
1150b
LO
113B
162
160
120a
S1
113A
113A'
bypass
17aa(26℃)
1141
17ab(29℃)
113B'
130a
HI
HO
LI
S2
120b
131a
132a
bypass
17bb(26℃)
161
HI= High Temp. Inlet
HO= High Temp. Outlet
LI= Low Temp. Inlet
LO= Low Temp. Outlet
High Temp. Cycle
Low Temp. Cycle
133
163

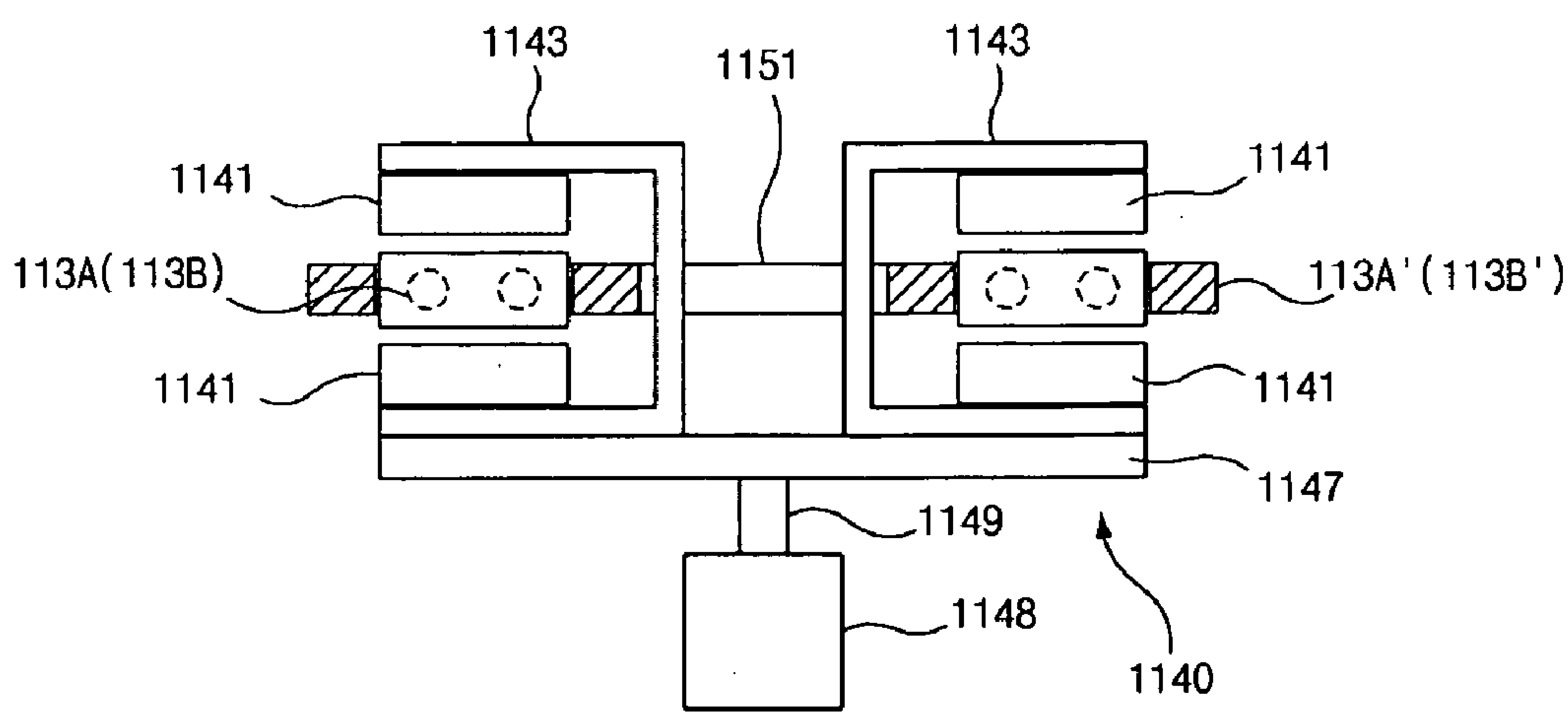
【FIGURE 15】


1150
17aa(26℃)
130b
HI
113B
162
160
120a
S1
113A
1141
113A'
bypass
17ab(29℃)
LO
113B'
LI
HO
131b
132b
133b
S2
17bb(26℃)
bypass
161
17bc(23℃)
High Temp. Cycle
Low Temp. Cycle
163

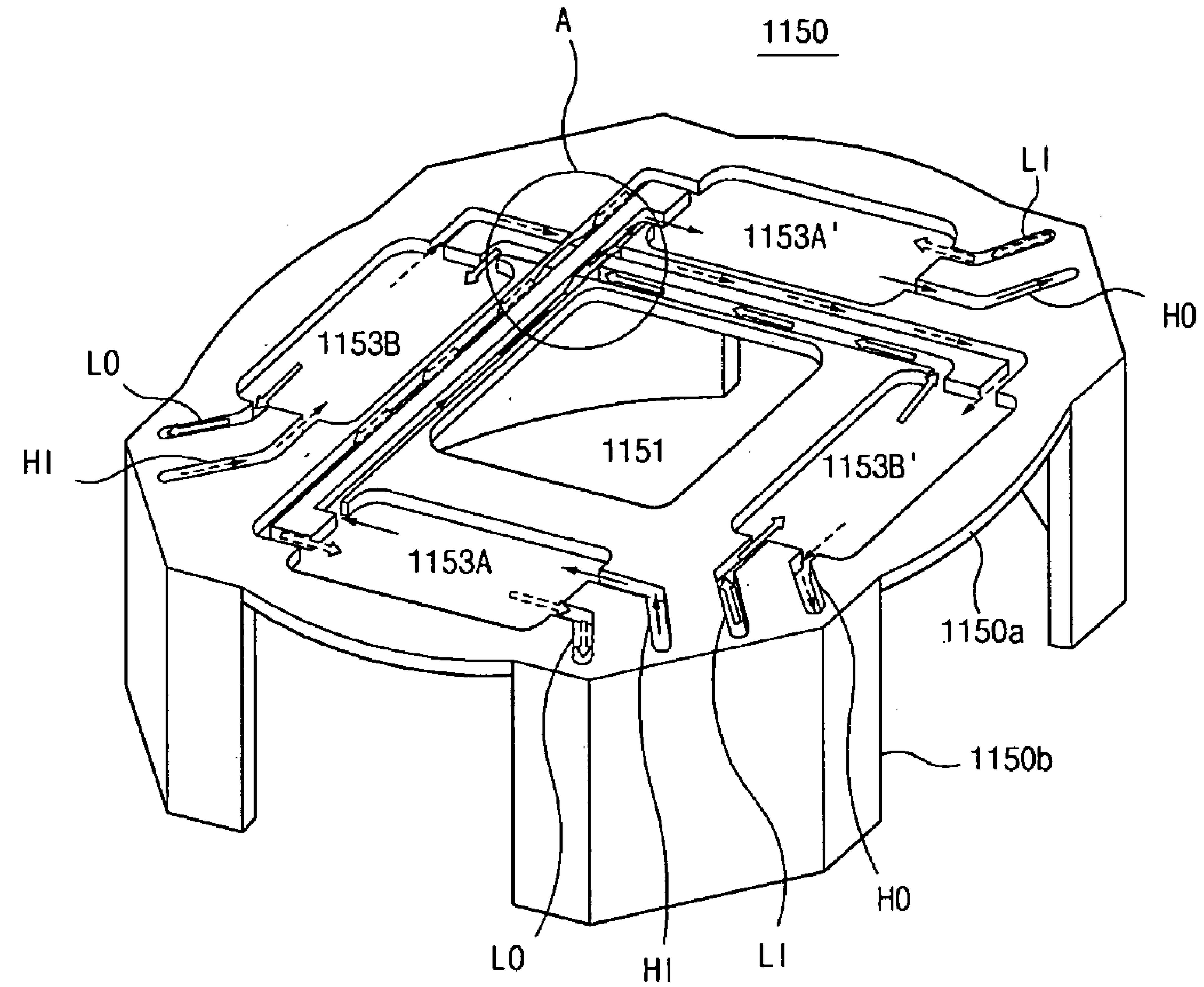
【FIGURE 16】



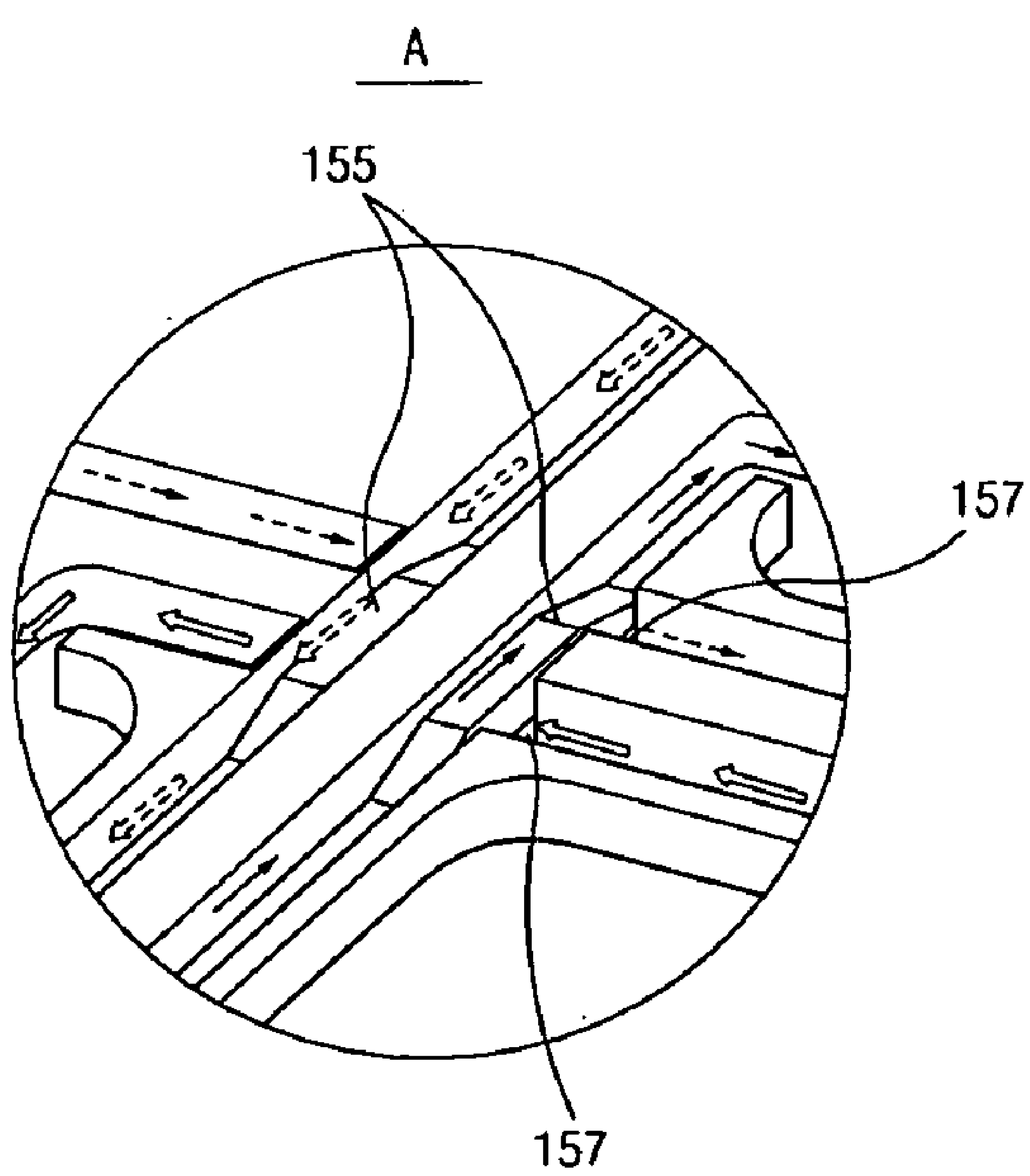
【FIGURE 17】



【FIGURE 18】



【FIGURE 19】



ACTIVE MAGNETIC REFRIGERATOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of International Application No. PCT/KR2006/004714, filed on Nov. 10, 2006, entitled "Active Magnetic Refrigerator," which claims priority under 35 U.S.C. §119 to Application No. KR 10-2006-0008730 filed on Jan. 27, 2006, entitled "Active Magnetic Refrigerator," and Application No. KR 10-2006-0020868 filed on Mar. 6, 2006, entitled "Active Magnetic Refrigerator," the entire contents of which are hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to an active magnetic refrigerator comprising separated hot and cold heat exchange units wherein a heat transfer fluid that exchanges a heat with a magnetic heat exchange unit having the magnetocaloric material pieces arranged to have a gap therebetween separately circulates through a solenoid valve.

BACKGROUND

[0003] A conventional active magnetic refrigerator is disclosed in U.S. Pat. No. 6,826,915. As shown in FIG. **1**, (a) a temperature of a magnetic refrigerant material which has a magnetic field applied thereto as a magnet moves to a right increases from a dotted line to a solid line. (b) The temperature of the magnetic refrigerant material drops from the dotted line to the solid line as a heat transfer fluid at a cold side moves to a hot side, and the heat transfer fluid is gradually heated to be hot at a right outlet, thereby emitting heat by an heat exchange with the hot side. (c) The temperature of the magnetic refrigerant material which has a magnetic field erased as the magnet moves to a left decreases more from the dotted line to the solid line. (d) Due to the movement of the heat transfer fluid from the hot side to the cold side, the magnetic refrigerant material is heated from the temperature of the dotted line to that of the solid line, and the heat transfer fluid is relatively cooled to be cold at a left outlet, thereby absorbing heat from the cold side to cool the cold side.

[0004] As shown in FIGS. **2** and **3**, in accordance with the conventional shuttle type active magnetic regenerator including the above-described cycle, a temperature of the heat transfer fluid heated in a first heat exchange unit **10**A in the magnetic field is dropped to an atmospheric temperature by a hot-side heat exchanger **70** and the heat transfer fluid is then passed through the second heat exchange unit **10**B. At the same time, since the second heat exchange unit **10**B is outside the magnetic field, a magnetic refrigerant material **16** has a low temperature, the temperature of the heat transfer fluid drops while passing through the magnetic refrigerant material layer **16**. The heat transfer fluid having the low temperature passes through a cold-side heat exchanger **60** and then enters the first heat exchange unit **10**A to be heated. The heat transfer fluid then flows to the hot-side heat exchanger **70**, the second heat exchange unit **10**B and the cold-side heat exchanger **60** to complete the one cycle.

[0005] Contrarily, when the second heat exchange unit **10**B is moved to a magnet circuit **22** by a movable mechanism **24**, a channel switch **30** reverses the flow of the heat transfer fluid to generate a reverse cycle.

[0006] A disadvantage of the conventional shuttle type active magnetic refrigerator is that a single heat transfer fluid circulates two magnetic heat exchange units **10**A and **190**B to serve as the hot side and the cold side simultaneously such that the heat exchange efficiency is degraded. For instance, when the magnet circuit **22** switched from the first magnetic heat exchange unit **10**A to the second magnetic heat exchange unit **10**B, the channel switch **30** operates. At the same time, the first magnetic heat exchange unit **10**A moves out of the magnetic field so that the temperature of the magnetocaloric material **16** drops rapidly. When the temperature drops, a coolant having the atmospheric temperature that has passed through the hot-side heat exchanger **70** should pass the first magnetic heat exchange unit **10**A in order to be effected by the rapidly cooled temperature. However, the heat transfer fluid having a high temperature that has not passed through the hot-side heat exchanger **70** is reversely circulated by the channel switch **30** to be returned to the AMR bed **10**. Therefore, the effect of the cooling is hardly obtained.

[0007] As shown in FIG. **3**, since the magnetic heat exchange unit **10** comprises the inlet/outlet ports **18***a* and **18***b* of the heat transfer fluid, the heat transfer fluid having the hot temperature in the magnetic heat exchange unit cannot be exhausted due to the reverse circulation when the channel switch **30** is in operation, thereby degrading the heat exchange efficiency.

[0008] In addition, since the conventional active magnetic refrigerator employs the single heat transfer fluid, an amount of the heat transfer fluid passing through the hot side cannot be controlled, and a heat of the magnetocaloric material **16** cannot be cooled promptly, resulting in a degradation of the heat exchange efficiency.

[0009] In addition, since a fine mesh **16** is used at the outlet port in order to prevent a problem that the magnetocaloric material **16** of a power type is lost by the heat transfer fluid (coolant), the coolant cannot be circulated smoothly.

[0010] Moreover, since the coolant continues to pass the magnetocaloric material **16** at the same spot, a smooth heat exchange is difficult.

[0011] In addition, the magnetocaloric material **16** having a microscopic size may be lost when the coolant enters or exits the magnetic heat exchange unit **10**.

[0012] A conventional rotation magnetic refrigerator is disclosed in U.S. Pat. No. 6,668,560. As shown in FIGS. **4** and **5**, in accordance with the conventional rotation magnetic refrigerator, while a heat transfer fluid **17** entering into a cold side inlet port **22** through a cold side inlet port pipe **21** flows to a hot side outlet port **34**, the heat transfer fluid **17** absorbs a heat generated by a magnetocaloric effect of a magnetocaloric material **12** having a magnetic field applied thereto and exits to a hot side outlet port pipe **33** through a hot side outlet port ports **34** to cool the magnetocaloric material **12**. A hot side sequentially passes the hot side outlet port pipe **33**, a valve **71**, a pump **60**, and a hot heat exchanger **62** and flows into a magnetic heat exchange compartment **13**. In a hot side inlet port pipe **31**, the hot side is divided into the hot side inlet port pipe **31** and a cold side outlet port **23**, and meets a cold side at a cold side outlet port pipe **24** and proceed to a valve **74**. When the hot side moves from a hot side inlet port **32** to the cold side outlet port pipe **24**, the hot side is cooled by passing the magnetocaloric material **12** already cooled by the hot side. The cold side that has passed through the valve **74** passes a cold heat exchanger **63** and flows to pipes **83** and **21** to repeat a cycle (a detailed description is omitted. See U.S. Pat. No. 6,668,560 for omitted reference numerals).

[0013] As described above, since the conventional rotation magnetic refrigerator comprises twelve magnetic heat exchange compartments, four valves **71**, **72**, **73** and **74** and more than 24 pipes, it is difficult to manufacture the conventional magnetic refrigerator.

[0014] Moreover, since the single heat transfer fluid is circulated to serve as the hot side and the cold side simultaneously. As shown in FIG. **5**, the heat transfer fluid enters the hot-side through the hot side inlet port **32** and cooled by passing through the cooled the magnetocaloric material to exit through the cold side inlet port **24** resulting in the degradation of the heat exchange efficiency. At this time, when the heat transfer fluid having a temperature lower than that of the hot side injected into the hot side inlet port **32** enters the hot side inlet port **32** and passes through the cooled magnetocaloric material, the heat transfer fluid having a lower temperature may be obtained at the cold side inlet port **24** resulting in an improvement of the heat exchange efficiency.

[0015] In addition, since the conventional active magnetic refrigerator employs the single heat transfer fluid, the amount of the heat transfer fluid passing through the hot side cannot be controlled, and a heat of the magnetocaloric material cannot be cooled promptly, resulting in a degradation of the heat exchange efficiency.

SUMMARY

[0016] It is an object of the present invention to provide an active magnetic refrigerator wherein a hot side and a cold side is dividedly circulated to provide a high heat exchange efficiency and to control an mount of the heat transfer fluid.

[0017] In order to achieve the above-described object, there is provided an active magnetic refrigerator, comprising: first and second heat exchange units including a magnetocaloric material for passing a flow of a heat transfer fluid; a magnet unit for applying a magnetic field to one of the first heat exchange unit and the second heat exchange unit or erasing the magnetic field from the first heat exchange unit or the second heat exchange unit; a hot heat exchanger for coupled to the first heat exchange unit and the second heat exchange unit for a circulation; a cold heat exchanger for coupled to the first heat exchange unit and the second heat exchange unit for the circulation; a first solenoid valve for directing a first heat transfer fluid exhausted from the hot heart exchanger to one of the first heat exchange unit and the second heat exchange unit having the magnetic field applied thereto; and a second solenoid valve for directing a second heat transfer fluid exhausted from the cold heart exchanger to one of the second heat exchange unit and the first heat exchange unit having the magnetic field erased therefrom.

[0018] In accordance with the refrigerator, a hot side and a cold side is dividedly circulated to provide a high heat exchange efficiency and to control an amount of the heat transfer fluid.

[0019] It is preferable that the magnet unit comprises a first electromagnet attached to the first heat exchange unit, and a second electromagnet attached to the second heat exchange unit.

[0020] In addition, when the magnet unit comprises a permanent magnet and a permanent magnet conveying member for moving the permanent magnet to one of the first heat exchange unit and the second heat exchange unit, a use of the plurality of the magnetic heat exchange units is possible with a single magnet unit.

[0021] It is preferable that the permanent magnet conveying member comprises a yoke having the permanent magnet disposed at both sides thereof, and a reciprocation transfer member for reciprocating of the yoke, wherein The refrigerator in accordance with claim **4**, wherein the reciprocation transfer member comprises a rack attached to the yoke, a pinion engaged with the rack, and a motor for transferring a rotational power to the pinion.

[0022] On the other hand, it is preferable that the magnet unit comprises a magnet and a magnet rotating assembly for rotating the magnet, and the refrigerator further comprises a plurality of mounting parts for mounting the first heat exchange unit and the second heat exchange unit, the mounting part being disposed on a rotational plane of the magnet, a through-hole having the magnet rotating assembly mounted at a center thereof, and a table for constituting a connecting path for connecting the heat exchangers and the magnetic heat exchange units.

[0023] It is preferable that the connecting path of a portion at a crossing of the first heat transfer fluid and the second heat transfer fluid comprises a tunnel and a bridge.

[0024] It is also preferable that the magnet rotating assembly comprises a flange supporting the magnet disposed upper and lower sides of one of the first heat exchange unit and the second heat exchange unit, a yoke consisting of a web connecting the flange, and a rotational power transfer member for transferring a rotational power to the yoke.

[0025] When the first heat exchange unit comprises a first case including the magnetocaloric material, an upper inlet port and an upper outlet port disposed on an upper surface of the first case, and an lower inlet port and an lower outlet port disposed on an lower surface of the first case, and the second heat exchange unit comprises a second case including the magnetocaloric material, an upper inlet port and an upper outlet port disposed on an upper surface of the second case, and an lower inlet port and an lower outlet port disposed on an lower surface of the second case, the cold side and the hot side is completely divided as to improve the heat exchange efficiency.

[0026] It is preferable that the magnetocaloric material comprises a plurality of magnetocaloric material pieces disposed in the first case or the second case, the plurality of magnetocaloric material pieces have a gap therebetween so that a mesh may not be used for a smooth flow of the heat transfer fluid.

[0027] It is preferable that each of the plurality of magnetocaloric material pieces comprises a gadolinium plate or a gadolinium rod having a constant circular cross-section in the lengthwise direction.

[0028] When the gadolinium rod comprises a groove in the lengthwise direction, a contact area is increased more resulting in an improvement of the heat exchange efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] FIG. **1** is a diagram illustrating a concept of an active magnetic refrigerator.

[0030] FIG. **2** is a diagram illustrating a configuration of a conventional active magnetic refrigerator.

[0031] FIG. **3** is a cross-sectional view illustrating a magnetic heat exchange unit for the active magnetic refrigerator of FIG. **2**.

[0032] FIG. **4** is a plan view illustrating a heat transfer fluid in another conventional active magnetic refrigerator.

[0033] FIG. **5** is a plan view exemplifying a magnetic heat exchange unit including a magnetocaloric material of a powder type of FIG. **4**.

[0034] FIG. **6** is a configuration diagram illustrating a magnetic refrigerator in accordance with a first preferred embodiment of the present invention.

[0035] FIG. **7** is a plan view illustrating a magnet unit for the active magnetic refrigerator of FIG. **6**.

[0036] FIG. **8** is a perspective view illustrating an exterior of the magnetic heat exchange unit for the active magnetic refrigerator of FIG. **6**.

[0037] FIG. **9** is a cross-sectional view of the magnetic heat exchange unit in accordance with the first preferred embodiment of the present invention taken along a line B-B of FIG. **8**.

[0038] FIGS. **10** through **12** are cross-sectional views of the magnetic heat exchange unit in accordance with another alternative example taken along a line B-B of FIG. **8**.

[0039] FIG. **13** is a perspective view illustrating a magnetocaloric material having a shape of a rod having a groove in a lengthwise direction.

[0040] FIGS. **14** and **15** are plan views illustrating a cycle of a heat transfer fluid according to a position of a magnet in accordance with an active magnetic refrigerator in accordance with a second preferred embodiment of the present invention.

[0041] FIG. **16** is a plan view illustrating the cycle of FIGS. **14** and **15** as one.

[0042] FIG. **17** is a schematic diagram illustrating a magnet rotating assembly.

[0043] FIGS. **18** and **19** are a perspective view and a partially magnified view of a table having a flow path.

DETAILED DESCRIPTION

[0044] The above-described objects and other objects and characteristics and advantages of the present invention will now be described in detail with reference to the accompanied drawings.

First Embodiment

[0045] FIG. **6** is a configuration diagram illustrating a magnetic refrigerator in accordance with a first preferred embodiment of the present invention, FIG. **7** is a plan view illustrating a magnet unit for the active magnetic refrigerator of FIG. **6**, and FIG. **8** is a perspective view illustrating an exterior of the magnetic heat exchange unit for the active magnetic refrigerator of FIG. **6**.

[0046] As shown in FIGS. **6** through **8**, the active magnetic refrigerator in accordance with the preferred embodiment of the present invention comprises a first magnetic heat exchange unit **113**A and a second magnetic heat exchange unit **113**B including a magnetocaloric material, a magnet unit **140** for applying a magnetic field to the first magnetic heat exchange unit **113**A and the second magnetic heat exchange unit **113**B or erasing the magnetic field therefrom, a hot heat exchanger **162**, a cold heat exchanger **163**, a first solenoid valve **120***a* and a second solenoid valve **120***b*.

[0047] The heat transfer fluid is divided into a first heat transfer fluids **17***aa* and **17***ab* circulating in the hot heat exchanger **162**, and a second heat transfer fluids **17***bb* and **17***bc* circulating in the cold heat exchanger **163** to form a cycle.

[0048] The first solenoid valve **120***a* is a 3-port 2-way solenoid valve for redirecting the first heat transfer fluid **17***aa* of a cold side flowing in a tube **130** of the hot heat exchanger **162** to a tube **131***a* through the first magnetic heat exchange unit **113**A or to a tube **131***b* through the second magnetic heat exchange unit **113**B such that the first heat transfer fluid **17***aa* flows in a tube **131**.

[0049] That is, the first solenoid valve **120***a* is disposed at a junction wherein the tube **130** is divided into tubes **130***a* and **130***b* connected to the first magnetic heat exchange unit **113**A and the second magnetic heat exchange unit **113**B.

[0050] Similarly, the second solenoid valve **120***b* is the 3-port 2-way solenoid valve for redirecting the second heat transfer fluid **17***bc* of a hot side flowing in a tube **132** of the cold heat exchanger **163** to a tube **133***a* through the second magnetic heat exchange unit **113**B or to a tube **133***b* through the first magnetic heat exchange unit **113**A such that the second heat transfer fluid **17***bc* flows in a tube **133**.

[0051] That is, the second solenoid valve **120***b* is disposed at a junction wherein the tube **132** is divided into tubes **132***a* and **132***b* connected to the second magnetic heat exchange unit **113**B and the first magnetic heat exchange unit **113**A.

[0052] As described above, since the first heat transfer fluids **17***aa* and **17***ab* of the hot side and the second heat transfer fluids **17***bb* and **17***bc* of the cold side is dividedly circulated as two cycles, a larger amount of the heat transfer fluid may be flown to the hot side by controlling an amount thereof to improve a heat exchange efficiency.

[0053] Moreover, it is preferable that the flow of the first heat transfer fluids **17***aa* and **17***ab* and the second heat transfer fluids **17***bb* and **17***bc* is generated by pumps **160** and **161**.

[0054] That is, as shown in FIG. **6**, the hot heat exchange circulating member and the cold heat exchange circulating member embodies a closed cycle similar to a closed circuit. Therefore, since an atmospheric pressure does not act on the heat transfer fluid directly, almost no resistance is applied to the pumps **160** and **161**, thereby reducing a time required for the heat exchange and improving the heat exchange efficiency.

[0055] The first magnetic heat exchange units **113**A and **113**B includes a magnetocaloric material **112** for passing the flow of the heat transfer fluid. The magnetocaloric material **112** comprises a gadolinium (Gd) of a fine powder type. The gadolinium has pores having a high osmosis to the flow of the heat transfer fluid, and a superior absorption and emission of a heat.

First Alternative Example

Magnetic Heat Exchange Unit 113

[0056] As shown in FIGS. **8** and **9**, a magnetic heat exchange unit **113** of the first alternative example a case **115** extending vertically, and a plurality of magnetocaloric material pieces **112** disposed in the case **115** to form a gap **114** therebetween.

[0057] Ports **115***a* and **116***b* are disposed on a top surface of the case **115**, and ports **115***b* and **116***a* are disposed on a bottom surface of the case **115**.

[0058] When the case **115** is the first magnetic heat exchange unit **113**A, the ports **115***a* and **116***b* are connected to the tubes **130***a* and **133***b*, and the ports **115***b* and **116***a* are connected to the tubes **131***a* and **132***b*.

[0059] When the case **115** is the second magnetic heat exchange unit **113**B, the ports **115***a* and **116***b* are connected to the tubes **130***b* and **133***a*, and the ports **115***b* and **116***a* are connected to the tubes **131***b* and **132***a*.

[0060] The case **115** may be manufactured by arranging and mounting the plurality of magnetocaloric material pieces **112** while the case **115** is disassembled in two parts, and then assembling, bonding or welding the parts.

[0061] The case **115** in accordance with the embodiment may be connected to the tube by the ports **115***a* and **116***b* and the ports **115***b* and **116***a* to be supported. The support improves the heat exchange efficiency by establishing an adiabatic state wherein the plurality of magnetocaloric material pieces **112** of the magnetic heat exchange unit **113** is not exposed.

[0062] The magnetocaloric material **112**, which have a shape of a plate manufactured from a gadolinium powder, are disposed in the case **115** in parallel such that the gap **114** prevents a contact therebetween. The plurality of magnetocaloric material pieces **112** of the gadolinium plate may be a thin foil or a thick sheet according to a flow velocity and a heat exchange rate of the heat transfer fluid.

[0063] As described above, the plurality of magnetocaloric material pieces **112** having the gap **114** therebetween prevents the loss of the material even when a mesh is not used, a contact with the entirety of the plurality of magnetocaloric material pieces **112** as well as a smooth flow is obtained since the heat transfer fluid flows through the gap **114**, and a higher heat exchange rate compared to that of the conventional art is obtained since a contact area is larger in case of the gadolinium plate.

Second Alternative Example

Magnetic Heat Exchange Unit **213**

[0064] As shown in FIG. **10**, the magnetic heat exchange unit **213** in accordance with the second alternative example comprises a plurality of magnetocaloric material pieces **212** having a shape of a rod instead of the plurality of magnetocaloric material pieces **112** having the shape of the plate. That is, each of the plurality of magnetocaloric material pieces **212** has the shape of the rod having a constant circular cross-section in the lengthwise direction.

[0065] A gap **214** between the plurality of magnetocaloric material pieces **212** having the shape of the rod is formed when in contact or not in contact due to the circular cross-section even when the plurality of magnetocaloric material pieces **212** are randomly arranged such that an effect of the first alternative example is obtained when the heat transfer fluid flows through the gap **214**.

[0066] It is preferable that the plurality of magnetocaloric material pieces **212** having the shape of the rod arranged vertically are tied as one to be inserted in a batch.

[0067] On the other hand, as shown in FIG. **13**, it is preferable that the plurality of magnetocaloric material pieces **212** having the shape of the rod comprises a groove **212***a* in a lengthwise direction to increase the contact area with the heat transfer fluid, thereby improving the heat exchange efficiency.

Third Alternative Example

Magnetic Heat Exchange Unit **313**

[0068] As shown in FIG. **11**, the magnetic heat exchange unit **313** in accordance with the third alternative example comprises a plurality of magnetocaloric material pieces **312** having the shape of the rod arranged to have a gap **314** therebetween similar to the plurality of magnetocaloric material pieces **112** having the shape of the plate of the first alternative example instead of a random arrangement of the plurality of magnetocaloric material pieces **212** having the shape of the rod of the second alternative example.

[0069] It is preferable that the plurality of magnetocaloric material pieces **312** having the shape of the rod arranged vertically are tied as one to be inserted in a batch.

[0070] As shown in FIG. **13**, it is preferable that the plurality of magnetocaloric material pieces **312** having the shape of the rod comprises the groove **212***a* in the lengthwise direction.

Fourth Alternative Example

Magnetic Heat Exchange Unit **413**

[0071] As shown in FIG. **12**, the magnetic heat exchange unit **413** in accordance with the fourth alternative example comprises a magnetocaloric material piece **412***a* having the shape of the rod and a magnetocaloric material piece **412***b* having the shape of the plate combined to have a gap **414** therebetween.

[0072] The magnet unit **140** may be attached to the magnetic heat exchange unit **113**.

[0073] Similar to the first embodiment, the magnet unit **140** may comprise a permanent magnet **141** disposed at both sides of the first magnetic heat exchange unit **113**A or the second magnetic heat exchange unit **113**B, and a permanent magnet conveying member for moving the permanent magnet **141** between the first magnetic heat exchange unit **113**A and the second magnetic heat exchange unit **113**B, or may comprises an electromagnet (not shown) attached to the first magnetic heat exchange unit **113**A and the second magnetic heat exchange unit **113**B to apply or erase the magnetic field. In addition, the magnet unit that is pushed toward or pulled away from (vertical to a paper surface of FIG. **7**) the first magnetic heat exchange unit **113**A and the second magnetic heat exchange unit **113**B may be embodied.

[0074] As shown in FIG. **7**, the permanent magnet conveying member comprises a yoke **143** having the permanent magnet **141** disposed at both sides thereof, and a reciprocation transfer member for carrying out a reciprocation of the yoke **143**.

[0075] The yoke **143** serves to concentrate the magnetic field of the permanent magnet **141** in a direction of the magnetic heat exchange unit **113** so that the magnetic field having a higher intensity is applied to the magnetic heat exchange unit.

[0076] The reciprocation transfer member may be embodied with a rack **145** attached to the yoke **143**, a pinion **147** engaged with the rack **145**, and a motor **149** a shaft of which transfers a rotational power to the pinion **147**. The rack **145** may be embodied by forming a tooth on a rod of a link of the yoke **143** or welding a separate rack to the rod.

[0077] It will be understood by those skilled in the art that various reciprocation transfer members that convert a rotational motion to a linear motion may be used in accordance with the present invention.

[0078] While FIG. **6** illustrates a case wherein the first magnetic heat exchange unit **113**A and the second magnetic heat exchange unit **113**B are disposed in parallel in order to show an entirety of the first magnetic heat exchange unit

113A and the second magnetic heat exchange unit 113B, it is preferable that the first magnetic heat exchange unit 113A and the second magnetic heat exchange unit 113B is disposed in line.

[0079] When the electromagnet is used, a current may be applied intermittently to embody applying or erasing the magnetic field.

[0080] The cycle of the active magnetic refrigerator employing the magnetic heat exchange unit **113** in accordance with the first alternative example of the present invention will now be described wherein the characteristic of the magnetocaloric material is subjected to an experiment by setting an atmospheric temperature which carries out an heat exchange with the hot heat exchanger **162**, and an atmospheric temperature which carries out an heat exchange with the cold heat exchanger **163** are set at 26° C. respectively, considering a characteristic of the magnetocaloric material wherein a temperature thereof rises by 3° C. when the magnetocaloric material is magnetized and drops by 3° C. when cooled by the heat transfer fluid.

[0081] The entire system except the magnet unit **140** is fixed and the magnet unit **140** is subjected to the reciprocation motion between the first magnetic heat exchange unit **113**A and the second magnetic heat exchange unit **113**B to alternately apply and erase the magnetic field.

[0082] A state wherein the magnet unit **140** is positioned at the first magnetic heat exchange unit **113**A is be described below.

[0083] When the magnetic field is applied to the magnetocaloric material of the first magnetic heat exchange unit **113**A, the first solenoid valve **120***a* is in operation to carry out a heat exchange wherein the first heat transfer fluid **17***aa* of the tube **130** (26° C.) is flown to the first magnetic heat exchange unit **113**A through the tube **130***a* with a pressure to cool the magnetocaloric material (29° C.) heated by the magnetic field to 26° C., and the first heat transfer fluid **17***ab* absorbs a heat to have a temperature of 29° C. A cycle is carried out wherein the first heat transfer fluid **17***ab* that carried out the heat exchange passes through the tube **131***a* and the tube **131** to carry out an heat exchange with an atmosphere at the hot heat exchanger **162** and cooled to the first heat transfer fluid **17***aa* of 26° C. (see thin solid line of FIG. **6**).

[0084] The second solenoid valve **120***b* at the second magnetic heat exchange unit **113**B that does not have any magnetic field applied thereto is operated to carry out an heat exchange wherein the second heat transfer fluid **17***bc* (26° C.) of the tube **132** is flown to the second magnetic heat exchange unit **113**B with a pressure through the tube **132***a* so as to heat the heat transfer fluid (23° C.) to 26° C., and the second heat transfer fluid **17***bc* is cooled to 23° C. After the second heat transfer fluid **17***bb* of 23° C. that carried out the heat exchange passes through the tube **133***a* and the tube **133** to carry out an heat exchange with an indoor at the cold heat exchanger **163**, the second heat transfer fluid **17***bc* of 23° C. passes through the second magnetic heat exchange unit **113**B. The above-described cycle is repeated to carry out the heat exchange (see thick solid line of FIG. **6**).

[0085] As described above, while the first solenoid valve **120***a* is a valve for redirecting the first heat transfer fluid to the first magnetic heat exchange unit **113**A or the second magnetic heat exchange unit **113**B so that the first heat transfer fluid may absorb the heat in the indoor and then emit the heat to the atmosphere, the second solenoid valve **120***bis* a valve for redirecting the second heat transfer fluid to the first magnetic heat exchange unit **113**A or the second magnetic heat exchange unit **113**B that does not have the magnetic field applied thereto so that the second heat transfer fluid **17** may be cooled and then may absorb the hear in the indoor. The redirecting function may be embodied by a simple program in a digital format.

[0086] As described above, the circulation of the heat transfer fluid is divided into the hot heat exchanger and the cold heat exchanger for the heat exchange of two cycles, thereby simplifying the structure of a magnetic refrigerating cycle.

[0087] In addition, in accordance with the system, since the heat transfer fluid at the atmospheric temperature is injected to the magnetocaloric material, the heat transfer fluid is heated and cooled more according to a state of the material to improve an efficiency of the heat exchanger.

[0088] Moreover, since the active magnetic refrigerator is divided into the hot heat exchanger and the cold heat exchanger, amounts of the first heat transfer fluid and the second heat transfer fluid **17***bb* are controlled to be different. Therefore, a larger amount of the first heat transfer fluid may be flown to the hot side of the magnetic heat exchange unit to maximize the cooling of the magnetocaloric material.

Second Embodiment

[0089] FIGS. **14** and **15** are plan views illustrating a cycle of a heat transfer fluid according to a position of a magnet in accordance with an active magnetic refrigerator in accordance with a second preferred embodiment of the present invention, FIG. **16** is a plan view illustrating the cycle of FIGS. **14** and **15** as one, FIG. **17** is a schematic diagram illustrating a magnet rotating assembly, and FIGS. **18** and **19** are a perspective view and a partially magnified view of a table having a flow path.

[0090] As shown in FIGS. **14** through **19**, the active magnetic refrigerator in accordance with the preferred embodiment of the present invention comprises a first magnetic heat exchange units **113**A and **113**A' and a second magnetic heat exchange units **113**B and **113**B' including a magnetocaloric material, a magnet **1141** attached to the magnetic heat exchange units **113**A, **113**A', **113**B and **113**B', a magnet rotating assembly **1140** for applying and erasing a magnetic field by rotating the magnet **1141**, a hot heat exchanger **162**, a cold heat exchanger **163**, a first solenoid valve **120***a* and a second solenoid valve **120***b*.

[0091] The heat transfer fluid is divided into a first heat transfer fluids **17***aa* and **17***ab* circulating in the hot heat exchanger **162**, and a second heat transfer fluids **17***bb* and **17***bc* circulating in the cold heat exchanger **163** to form a cycle.

[0092] A plurality of the first magnetic heat exchange units **113**A and **113**A' are disposed on a left and a right and a plurality of the second magnetic heat exchange units **113**B and **113**B' are disposed at a top and a bottom from a plan view.

[0093] The first solenoid valve **120***a* is a 3-port 2-way solenoid valve for redirecting the first heat transfer fluid **17***aa* of the cold side exhausted from the hot heat exchanger **162** to the first magnetic heat exchange units **113**A and **113**A' through the tube **130***a* or to the second magnetic heat exchange units **113**B and **133**B' through the tube **130***b* such that the first heat transfer fluid **17***ab* that has carried out a heat exchange flows into the cold heat exchanger **163**.

[0094] That is, the first solenoid valve **120***a* is disposed at a junction wherein the tube **130***a* or the tube **130***b* connected to the first magnetic heat exchange unit **113**A or the second magnetic heat exchange unit **113**B is divided.

[0095] Similarly, the second solenoid valve **120***b* is the 3-port 2-way solenoid valve for redirecting the second heat transfer fluid **17***bb* of the hot side exhausted from the cold heat exchanger **163** to the second magnetic heat exchange units **113**B and **113**B' through the tube **132***a* or to the second magnetic heat exchange units **113**B and **133**B' through the tube **130***b* such that the first heat transfer fluid **17***ab* that has carried out a heat exchange flows into the cold heat exchanger **163**.

[0096] That is, the second solenoid valve **120***b* is disposed at a junction wherein the tube **132***a* or the tube **132***b* connected to the second magnetic heat exchange unit **113**B' or the first magnetic heat exchange unit **113**A' is divided.

[0097] As described above, since the first heat transfer fluids **17***aa* and **17***ab* of the hot side and the second heat transfer fluids **17***bb* and **17***bc* of the cold side is dividedly circulated as two cycles, a larger amount of the heat transfer fluid may be flown to the hot side by controlling an amount thereof to improve a heat exchange efficiency.

[0098] Since the magnetic heat exchange units **113**A, **113**A', **113**B and **113**B' are similar to those of the first embodiment, a detailed description is thereby omitted.

[0099] In addition, it is preferable that the magnetic heat exchange units **113**A, **113**A', **113**B and **113**B' are mounted on a table **1150**. As shown in FIG. **18**, the table **1150** comprises an upper plate **1150***a* having mounting parts **1153**A, **1153**A', **1153**B and **1153**B' formed therein for mounting the magnetic heat exchange units **113**A, **113**A', **113**B and **113**B' having a predetermined distance therebetween, and a connecting path for connecting the tubes **130***a*, **131***a*, **132***a*, **133***a*, **130***b*, **131***b*, **132***b* and **133***b* and the upper plate **1150***a* as well as supporting the upper plate **1150***a*. The mounting parts **1153**A and **1153**B may be embodied by a groove or a through-hole.

[0100] Particularly, as shown in FIG. **19**, a mixing of the first heat transfer fluid and the second heat transfer fluid is prevented at a crossing thereof by employing a bridge **1155** and a tunnel **1157** in the connecting path inside the upper plate **1150***a*. The bridge **1155** has a form of elevated overpass which is thicker than other connecting path to allow a facile formation of the tunnel **1157**.

[0101] Due to the bridge **1155** and the tunnel **1157**, a thickness of the upper plate **1150***a* is minimized.

[0102] The magnet rotating assembly **1140** for applying the magnetic field to the first magnetic heat exchange units **113**A and **113**A' or the second magnetic heat exchange units **113**B and **113**B' or erasing the magnetic field therefrom by rotating the magnet **1141** may be mounted on a through-hole **1151** punched at a center of the upper plate **1150***a*.

[0103] The magnet rotating assembly **1140** rotates the magnet **1141** disposed at both sides of the first magnetic heat exchange units **113**A and **113**A' or the second magnetic heat exchange units **113**B and **113**B' to the second magnetic heat exchange units **113**B and **113**B' or the first magnetic heat exchange units **113**A and **113**A'. That is, as shown in FIG. **17**, it is preferable that the magnet rotating assembly **1140** comprises a plurality of yokes **1143** having the magnet **1141** disposed at both sides thereof, a rotation support **1147** for supporting the magnet **1141**, and a rotational power transfer member for rotating the rotation support **1147**.

[0104] The rotational power transfer member may be embodied by a motor **1148**, a rotating shaft **1149** for transferring a rotational power of the motor **1148** to the rotation support **1147**.

[0105] It should be understood by the skilled in the art that various rotational power transfer members may be embodied such as directly connecting the rotating shaft **1149** to the plurality of yokes **1143** for a rotation or using a belt to rotate the plurality of yokes **1143**.

[0106] The cycle of the active magnetic refrigerator employing the magnetic heat exchange units **113**A, **113**A', **113**B and **113**B' in accordance with the second embodiment of the present invention will now be described wherein the characteristic of the magnetocaloric material is subjected to an experiment by setting an atmospheric temperature which carries out an heat exchange with the hot heat exchanger **162**, and an atmospheric temperature which carries out an heat exchange with the cold heat exchanger **163** are set at 26° C. respectively, considering a characteristic of the magnetocaloric material wherein a temperature thereof rises by 3° C. when the magnetocaloric material is magnetized and drops by 3° C. when cooled by the heat transfer fluid.

[0107] The entire system except the magnet **1141** is fixed and only the magnet **1141** is rotated by the magnet rotating assembly **1140** to alternately apply the magnetic field to the magnetocaloric material of the first magnetic heat exchange units **113**A and **113**A' or the second magnetic heat exchange units **113**B and **113**B'.

[0108] As shown in FIG. **14**, a state wherein the magnet **1141** is positioned at the first magnetic heat exchange units **113**A and **113**A' at the right and left thereof is be described below.

[0109] When the magnetic field is applied to the magnetocaloric material of the first magnetic heat exchange units **113**A and **113**A', the first solenoid valve **120***a* is in operation to carry out a heat exchange wherein the first heat transfer fluid **17***aa* of 26° C. is flown to the first magnetic heat exchange units **113**A and **113**A' through the tube **130***a* with a pressure to cool the magnetocaloric material (29° C.) heated by the magnetic field to 26° C., and the first heat transfer fluid **17***ab* absorbs a heat to have a temperature of 29° C. A cycle is carried out wherein the first heat transfer fluid **17***ab* that carried out the heat exchange passes through the tube **131***a* to carry out an heat exchange with an atmosphere at the hot heat exchanger **162** and cooled to the first heat transfer fluid **17***aa* of 26° C. (see thin solid line arrow of FIGS. **14** and **15**).

[0110] The second solenoid valve **120***b* at the second magnetic heat exchange units **113**B and **113**B' that do not have any magnetic field applied thereto is operated to carry out an heat exchange wherein the second heat transfer fluid **17***bb* having the temperature of 26° C. is flown to the second magnetic heat exchange units **113**B and **113**B' with a pressure through the tube **132***a* so as to heat the heat transfer fluid having the temperature of 23° C. to 26° C., and the second heat transfer fluid **17***bc* is cooled to 23° C. After the second heat transfer fluid **17***bc* of 23° C. that carried out the heat exchange passes through the tube **133***a* to carry out an heat exchange with the indoor at the cold heat exchanger **163**, the second heat transfer fluid **17***bb* passes through the second magnetic heat exchange units **113**B. The above-described cycle is repeated to carry out the heat exchange (see thick solid line arrow of FIGS. **14** and **15**).

[0111] On the other hand, as shown in FIG. **15**, a state wherein the magnet **1141** is rotated to be positioned at the second magnetic heat exchange units **113**B and **113**B' at the top and the bottom is described below.

[0112] When the magnetic field is applied to the magnetocaloric material of the second magnetic heat exchange units **113**B and **113**B', the first solenoid valve **120***a* is in operation to carry out a heat exchange wherein the first heat transfer fluid **17***aa* of 26° C. is flown to the second magnetic heat exchange units **113**B and **113**B' through the tube **130***b* with a pressure to cool the magnetocaloric material (29° C.) heated by the magnetic field to 26° C., and the first heat transfer fluid **17***ab* absorbs a heat to have a temperature of 29° C. A cycle is carried out wherein the first heat transfer fluid **17***ab* that carried out the heat exchange passes through the tube **131***b* to carry out an heat exchange with an atmosphere at the hot heat exchanger **162** and cooled to the first heat transfer fluid **17***aa* of 26° C. (see thin dotted line arrow of FIGS. **14** and **16**).

[0113] The second solenoid valve **120***b* at the first magnetic heat exchange units **113**A and **113**A' that do not have any magnetic field applied thereto is operated to carry out an heat exchange wherein the second heat transfer fluid **17***bb* having the temperature of 26° C. is flown to the first magnetic heat exchange units **113**A and **113**A' with a pressure through the tube **132***b* so as to heat the heat transfer fluid having the temperature of 23° C. to 26° C., and the second heat transfer fluid **17***bc* is cooled to 23° C. After the second heat transfer fluid **17***bc* of 23° C. that carried out the heat exchange passes through the tube **133***b* to carry out an heat exchange with the indoor at the cold heat exchanger **163**, the second heat transfer fluid **17***bb* of 23° C. passes through the first magnetic heat exchange units **113**A and **113**A'. the above-described cycle is repeated to carry out the heat exchange (see thick dotted line of FIGS. **14** and **16**).

[0114] As described above, while the first solenoid valve **120***a* is a valve for redirecting the first heat transfer fluid to the first magnetic heat exchange units **113**A and **113**A' or the second magnetic heat exchange units **113**B and **113**B' so that the first heat transfer fluid may absorb the heat in the indoor and then emit the heat to the atmosphere, the second solenoid valve **120***bis* a valve for redirecting the second heat transfer fluid to the first magnetic heat exchange units **113**A and **113**A' or the second magnetic heat exchange units **113**B and **113**B' that do not have the magnetic field applied thereto so that the second heat transfer fluid may be cooled and then may absorb the hear in the indoor. The redirecting function may be embodied by a simple program in a digital format.

[0115] As described above, the circulation of the heat transfer fluid is divided into the hot heat exchanger and the cold heat exchanger for the heat exchange of two cycles, thereby simplifying the structure of a magnetic refrigerating cycle.

[0116] While the present invention has been particularly shown and described with reference to the preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be effected therein without departing from the spirit and scope of the invention as defined by the appended claims.

[0117] As described above, the circulation of the heat transfer fluid is divided into the hot heat exchanger and the cold heat exchanger for the heat exchange of two cycles, thereby simplifying the structure of a magnetic refrigerating cycle.

[0118] Moreover, since the magnetic refrigerator is divided into the hot heat exchanger and the cold heat exchanger, amounts of the first heat transfer fluid and the second heat transfer fluid **17***bb* are controlled to be different. Therefore, a larger amount of the first heat transfer fluid may be flown to the hot side of the magnetic heat exchange unit to maximize the cooling of the magnetocaloric material.

[0119] In addition, the adiabatic state wherein the magnetocaloric material piece is not exposed may be achieved to improve the heat exchange efficiency.

[0120] Moreover, the hot heat exchange circulating member and the cold heat exchange circulating member embodies the close cycle similar to the closed circuit. Therefore, since the atmospheric pressure does not act on the heat transfer fluid directly, almost no resistance is applied to the pump, thereby reducing the time required for the heat exchange and improving the heat efficiency. This allows a use of a single pump since the pressure adjustment range is increased according to a size and the heat efficiency of the magnetic heat exchange unit.

[0121] In addition, each of the hot side and the cold side has dedicated ports (two in the upper portion, two in the lower portion), the hot and cold heat transfer fluids are not mixed resulting in the high heat exchange efficiency.

[0122] The magnetic heat exchange unit is constructed to comprise the case and the plurality of magnetocaloric material pieces disposed in the case to form the gap so that the heat transfer fluid may be flown through the gap, thereby improving the heat exchange efficiency through a uniform contact between the plurality of magnetocaloric material pieces and the heat transfer fluid and eliminating a need for the mesh for the smooth flow of the heat transfer fluid.

[0123] Moreover, the magnetocaloric material piece is embodied to have the shape of the plate or the rod, the magnetocaloric material piece is not easily lost.

[0124] In addition, since the magnet unit comprises the yoke and the reciprocation transfer member, the magnetic field may be applied or erased with the magnetic heat exchange unit being fixed, and the yoke concentrates the magnetic field of the permanent magnet toward the direction of the magnetic heat exchange unit to apply the high intensity magnetic field to the magnetic heat exchange unit

[0125] Moreover, the heat exchange efficiency is improved by increasing the contact area with the heat transfer fluid when the groove is formed on the plurality of magnetocaloric material pieces having the shape of the rod in the lengthwise direction.

[0126] In addition, the active magnetic refrigerator comprises the table which includes a plurality of mounting parts for mounting the first magnetic heat exchange unit and the second magnetic heat exchange unit disposed on the rotational plane of the magnet, a through-hole having the magnet rotating assembly mounted at the center thereof, and a table for constituting a connecting path for connecting the heat exchangers and the magnetic heat exchange units such that an installation of the magnetic heat exchange unit is simplified, the formation of the connecting path for connecting the heat exchanges is possible, and a layout of the tube is superior.

[0127] Moreover, since the connecting path at a crossing of the first heat transfer fluid and the second heat transfer fluid has the form of the tunnel and the bridge, the mixing of the fluids is prevented while maintaining the superior layout of the tube.

[0128] In addition, since the magnet rotating assembly comprises the yoke and the rotational power transfer member, the magnetic field may be applied or erased while the magnetic heat exchange unit being fixed, and the yoke concentrates the magnetic field of the magnet toward the direction of the magnetic heat exchange unit to apply the high intensity magnetic field to the magnetic heat exchange unit.

LIST OF REFERENCE SIGNS

[0129] **160**, **161**: pump
[0130] **162**: hot heat exchanger
[0131] **163**: cold heat exchanger
[0132] **17***aa*, **17***ab*: first heat transfer fluids
[0133] **17***bb*, **17***bc*: second heat transfer fluids
[0134] **112**, **212**, **312**, **412***a*, **412***b*: magnetocaloric material pieces (Gd)
[0135] **113**, **213**, **313**, **413**: magnetic heat exchange units
[0136] **114**, **214**, **314**, **414**: gaps
[0137] **115**: case
[0138] **115***a*, **115***b*': outlet ports
[0139] **115***a*', **115***b*: inlet ports
[0140] **130**, **131**, **132**, **133**: tube
[0141] **140**: magnet unit
[0142] **141**: permanent magnet
[0143] **143**: yoke
[0144] **145**: rack
[0145] **147**: pinion
[0146] **149**: motor shaft
[0147] **1140**: magnet rotating assembly
[0148] **1141**: magnet
[0149] **1143**: yoke
[0150] **1147**: rotation support.
[0151] **1148**: motor
[0152] **1149**: motor shaft
[0153] **1150**: table
[0154] **1150***a*: upper plate
[0155] **1150***b*: leg
[0156] **1153**A, **1153**B: mounting part
[0157] **1155**: bridge
[0158] **1157**: tunnel

What is claimed is:

1. An active magnetic refrigerator, comprising:
first and second heat exchange units including a magnetocaloric material for passing a flow of a heat transfer fluid;
a magnet unit for applying a magnetic field to one of the first heat exchange unit and the second heat exchange unit or erasing the magnetic field from the first heat exchange unit or the second heat exchange unit;
a hot heat exchanger for coupled to the first heat exchange unit and the second heat exchange unit for a circulation;
a cold heat exchanger for coupled to the first heat exchange unit and the second heat exchange unit for the circulation;
a first solenoid valve for directing a first heat transfer fluid exhausted from the hot heart exchanger to one of the first heat exchange unit and the second heat exchange unit having the magnetic field applied thereto; and
a second solenoid valve for directing a second heat transfer fluid exhausted from the cold heart exchanger to one of the second heat exchange unit and the first heat exchange unit having the magnetic field erased therefrom.

2. The refrigerator in accordance with claim **1**, wherein the magnet unit comprises a first electromagnet attached to the first heat exchange unit, and a second electromagnet attached to the second heat exchange unit.

3. The refrigerator in accordance with claim **1**, wherein the magnet unit comprises a permanent magnet and a permanent magnet conveying member for moving the permanent magnet to one of the first heat exchange unit and the second heat exchange unit.

4. The refrigerator in accordance with claim **3**, wherein the permanent magnet conveying member comprises a yoke having the permanent magnet disposed at both sides thereof, and a reciprocation transfer member for reciprocating of the yoke.

5. The refrigerator in accordance with claim **4**, wherein the reciprocation transfer member comprises a rack attached to the yoke, a pinion engaged with the rack, and a motor for transferring a rotational power to the pinion.

6. The refrigerator in accordance with claim **1**, wherein the magnet unit comprises a magnet and a magnet rotating assembly for rotating the magnet, and
further comprising a plurality of mounting parts for mounting the first heat exchange unit and the second heat exchange unit, the mounting part being disposed on a rotational plane of the magnet, a through-hole having the magnet rotating assembly mounted at a center thereof, and a table for constituting a connecting path for connecting the heat exchangers and the magnetic heat exchange units.

7. The refrigerator in accordance with claim **6**, wherein the connecting path of a portion at a crossing of the first heat transfer fluid and the second heat transfer fluid comprises a tunnel and a bridge.

8. The refrigerator in accordance with claim **7**, wherein the magnet rotating assembly comprises a flange supporting the magnet disposed upper and lower sides of one of the first heat exchange unit and the second heat exchange unit, a yoke consisting of a web connecting the flange, and a rotational power transfer member for transferring a rotational power to the yoke.

9. The refrigerator in accordance with claim **1**, wherein the first heat exchange unit comprises a first case including the magnetocaloric material, an upper inlet port and an upper outlet port disposed on an upper surface of the first case, and an lower inlet port and an lower outlet port disposed on an lower surface of the first case, and
wherein the second heat exchange unit comprises a second case including the magnetocaloric material, an upper inlet port and an upper outlet port disposed on an upper surface of the second case, and a lower inlet port and a lower outlet port disposed on a lower surface of the second case.

10. The refrigerator in accordance with claim **9**, wherein the magnetocaloric material comprises a plurality of magnetocaloric material pieces disposed in the first case or the second case, the plurality of magnetocaloric material pieces have a gap therebetween.

11. The refrigerator in accordance with claim **10**, wherein each of the plurality of magnetocaloric material pieces comprises a gadolinium plate.

12. The refrigerator in accordance with claim **10**, wherein each of the plurality of magnetocaloric material pieces comprises a gadolinium rod having a constant circular cross-section in the lengthwise direction.

13. The refrigerator in accordance with claim **12**, wherein the gadolinium rod comprises a groove in the lengthwise direction.

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