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Ohta et al.

(54) **HEAT REMOVAL METHOD AND HEAT REMOVAL APPARATUS**

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(52) **U.S. Cl.** **165/104.21**; 165/104.33

(57) **ABSTRACT**

A heat removal apparatus able to remove heat with a high heat flux from a large area is provided. A heat removal apparatus **1** has a heat removal use channel **31** provided adjacent to a heat removal object HO and a liquid supply use channel **32** extending along the heat removal use channel **31** and through which a liquid state refrigerant flows. In a wall portion **36*a*** partitioning the heat removal use channel **31** and the liquid supply use channel **32**, communicating holes **38** communicating the heat removal use channel **31** and the liquid supply use channel **32** are provided at a plurality of positions. The liquid state refrigerant is supplied from the liquid supply use channel **32** to the heat removal use channel **31** via the communicating holes **38**, whereby a liquid film is formed on an inner circumferential surface of the heat removal use channel **31**. The liquid film evaporates by the heat from the heat removal object HO, and the evaporated refrigerant is discharged from the heat removal use channel **31**.

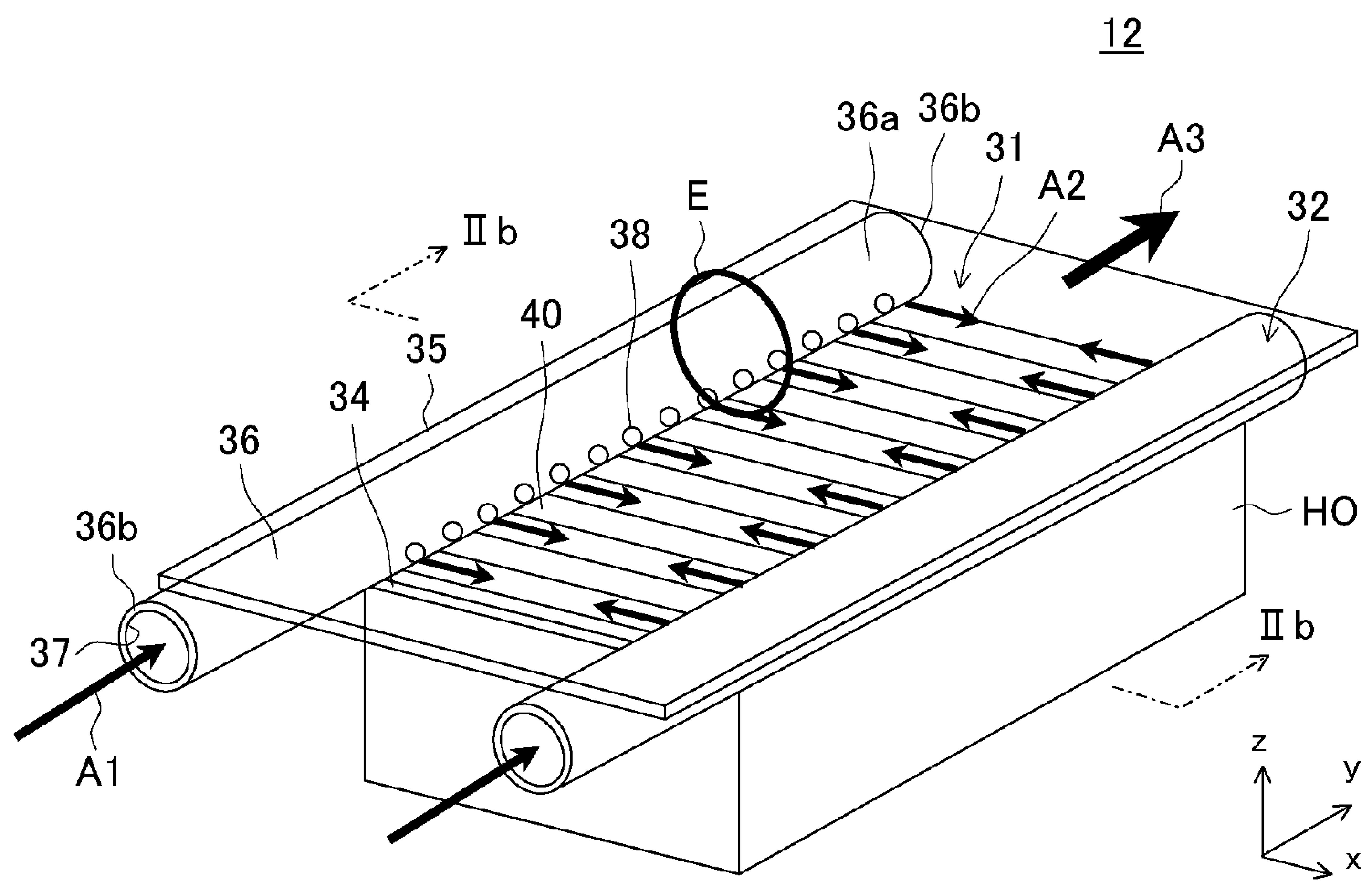


FIG. 1

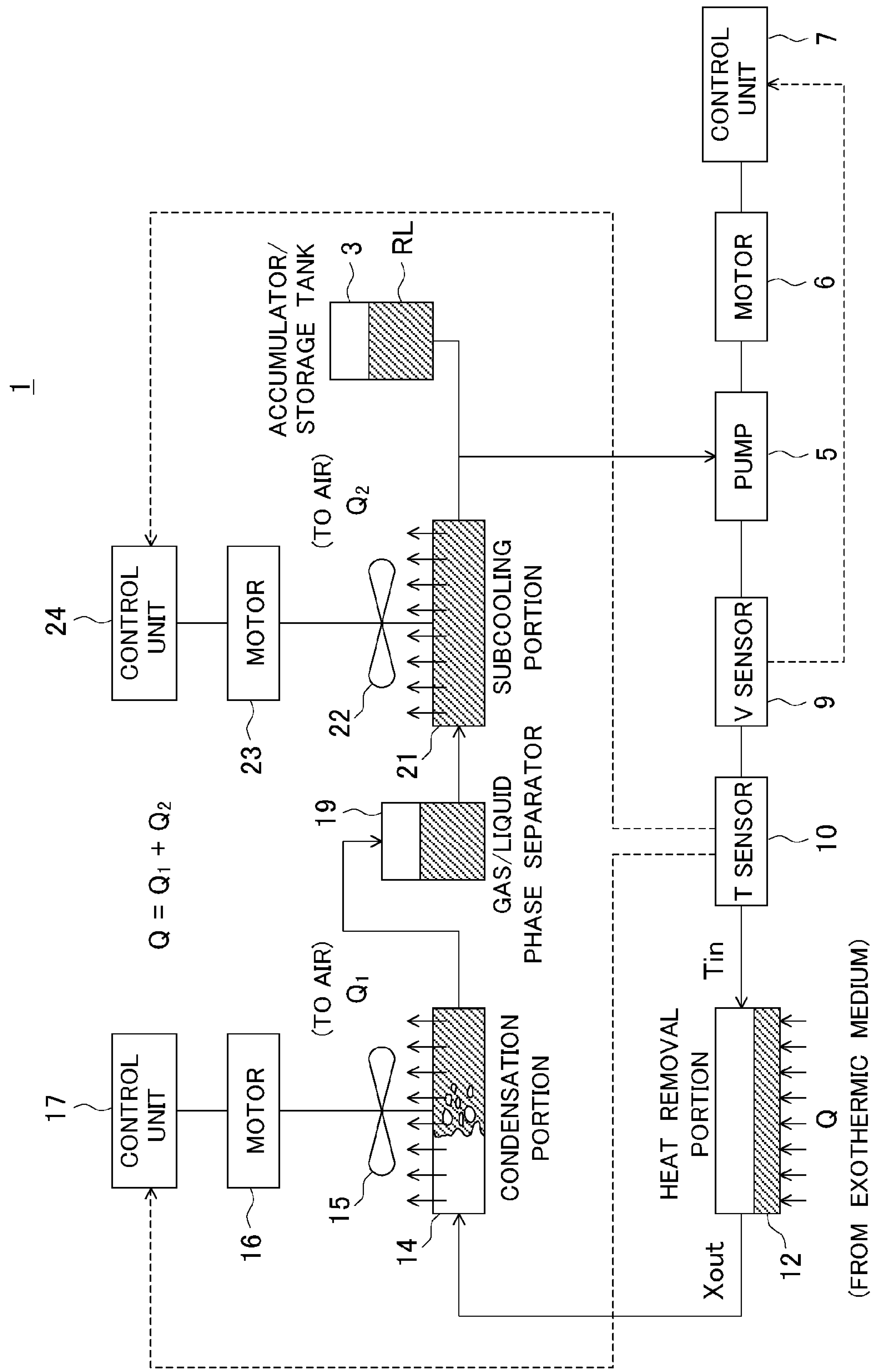

1
Q = Q_1 + Q_2
CONTROL UNIT
17
MOTOR
16
15
(TO AIR)
Q_1
14
CONDENSATION PORTION
19
GAS/LIQUID PHASE SEPARATOR
CONTROL UNIT
24
MOTOR
23
22
(TO AIR)
Q_2
21
SUBCOOLING PORTION
ACCUMULATOR/ STORAGE TANK
3
RL
Xout
HEAT REMOVAL PORTION
12
Q
(FROM EXOTHERMIC MEDIUM)
Tin
T SENSOR
10
V SENSOR
9
PUMP
5
MOTOR
6
CONTROL UNIT
7

FIG. 2A

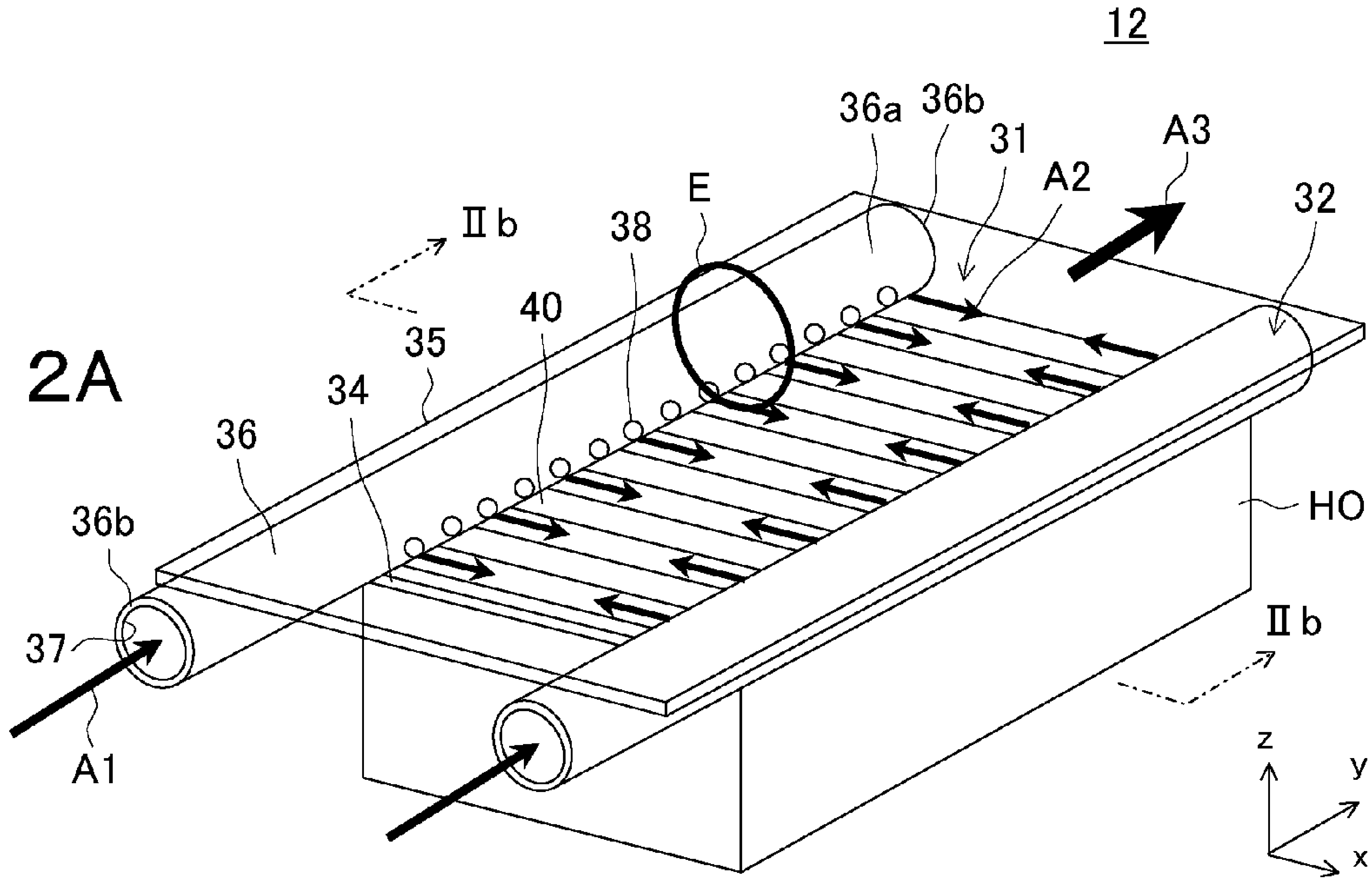


FIG. 2B

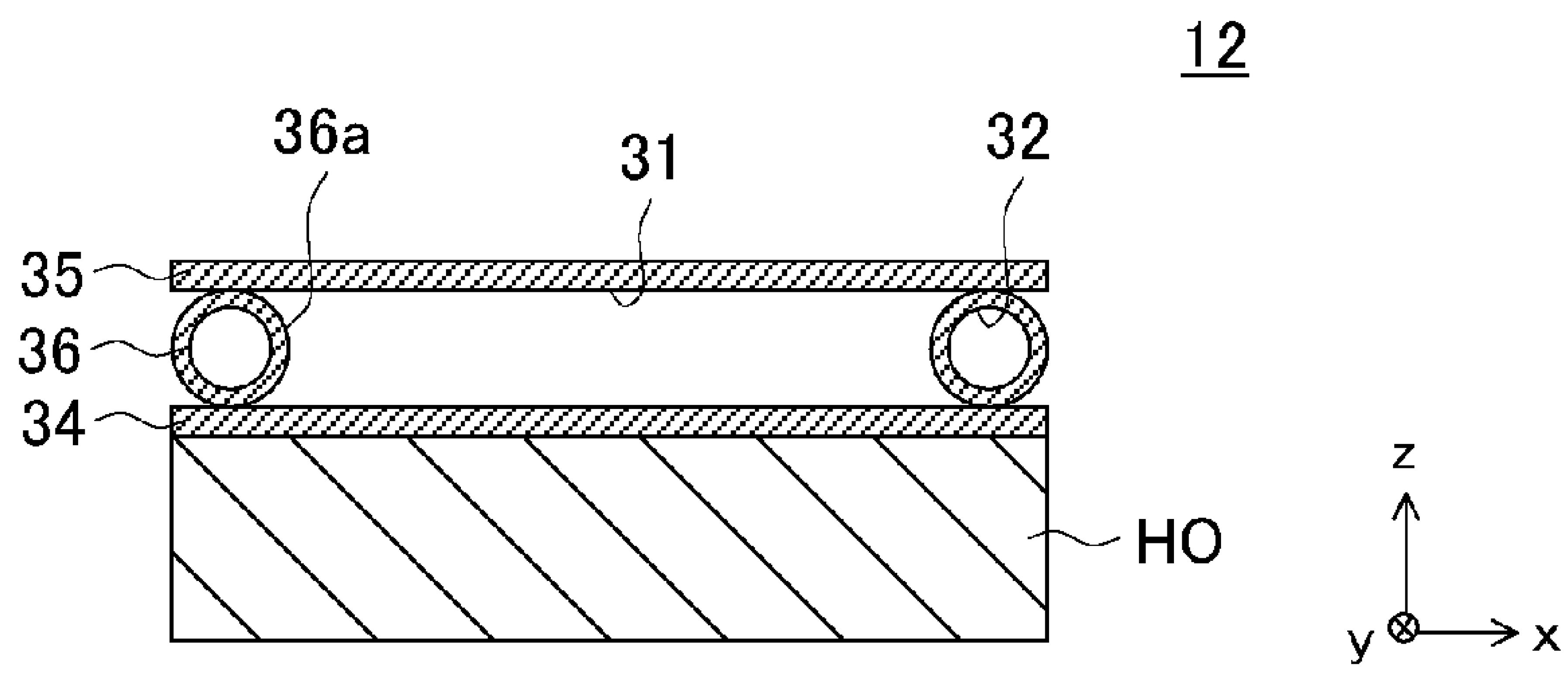


FIG. 2C

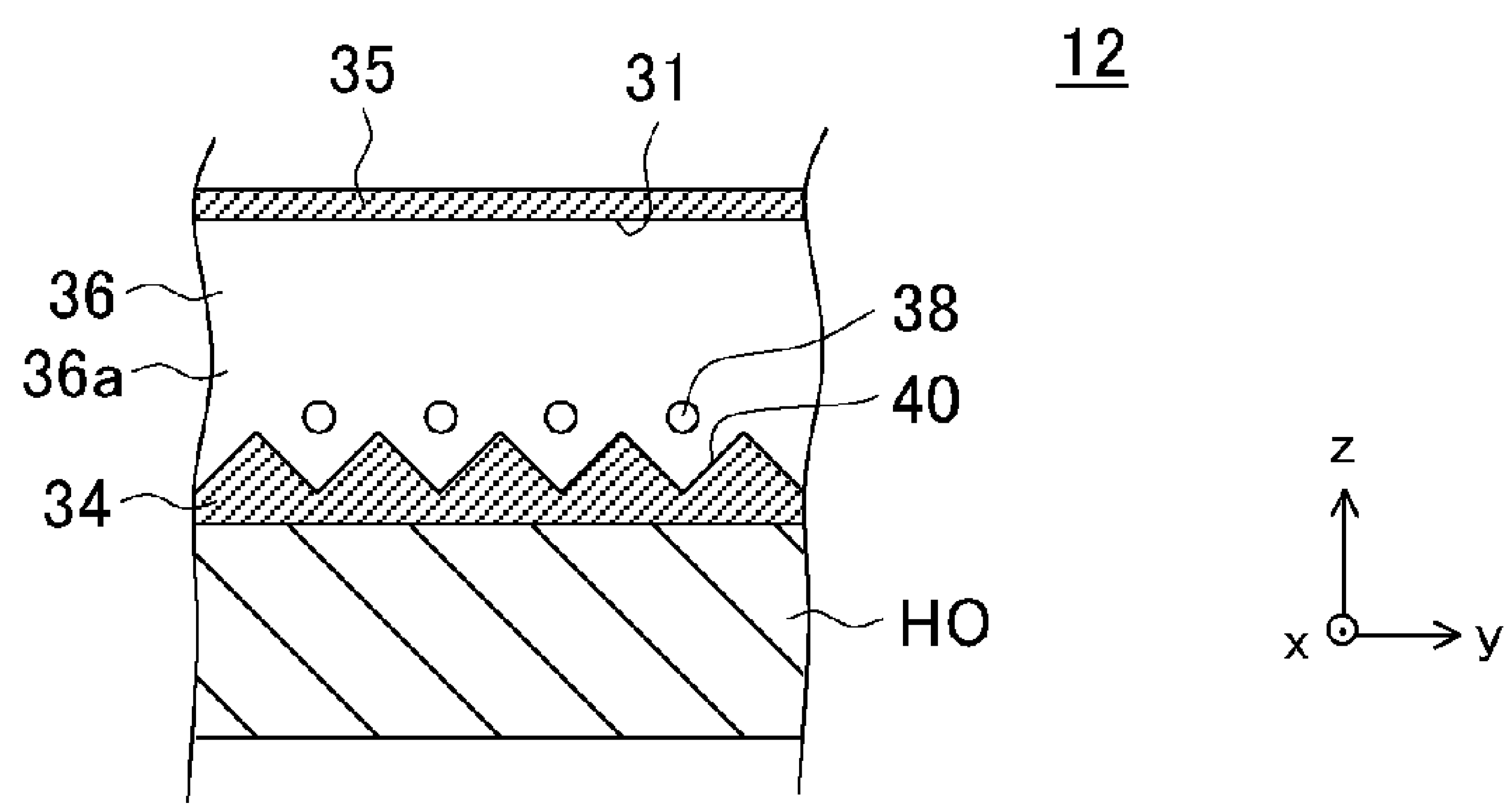


FIG. 3

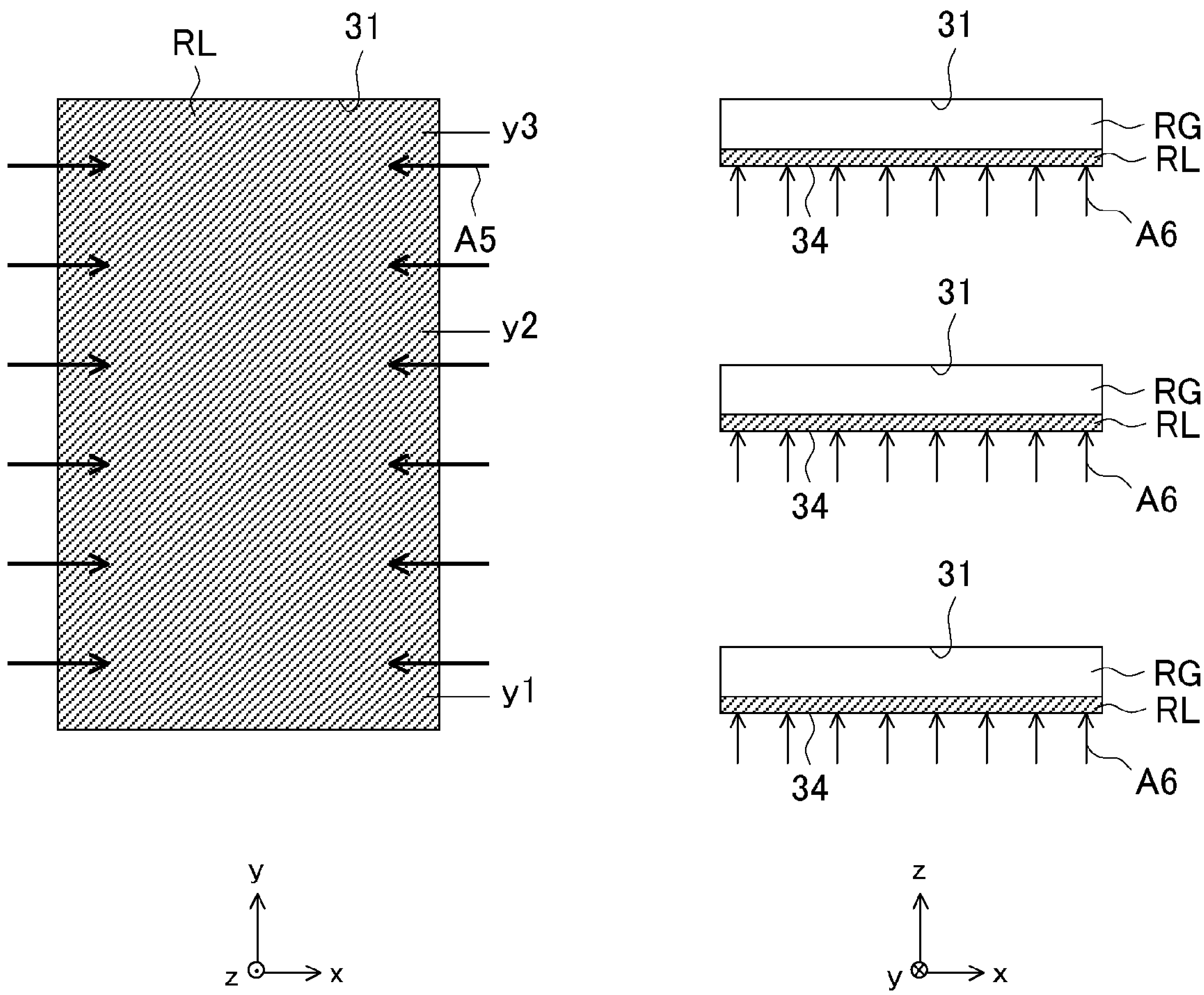


FIG. 4A

FIG. 4B

FIG. 4C

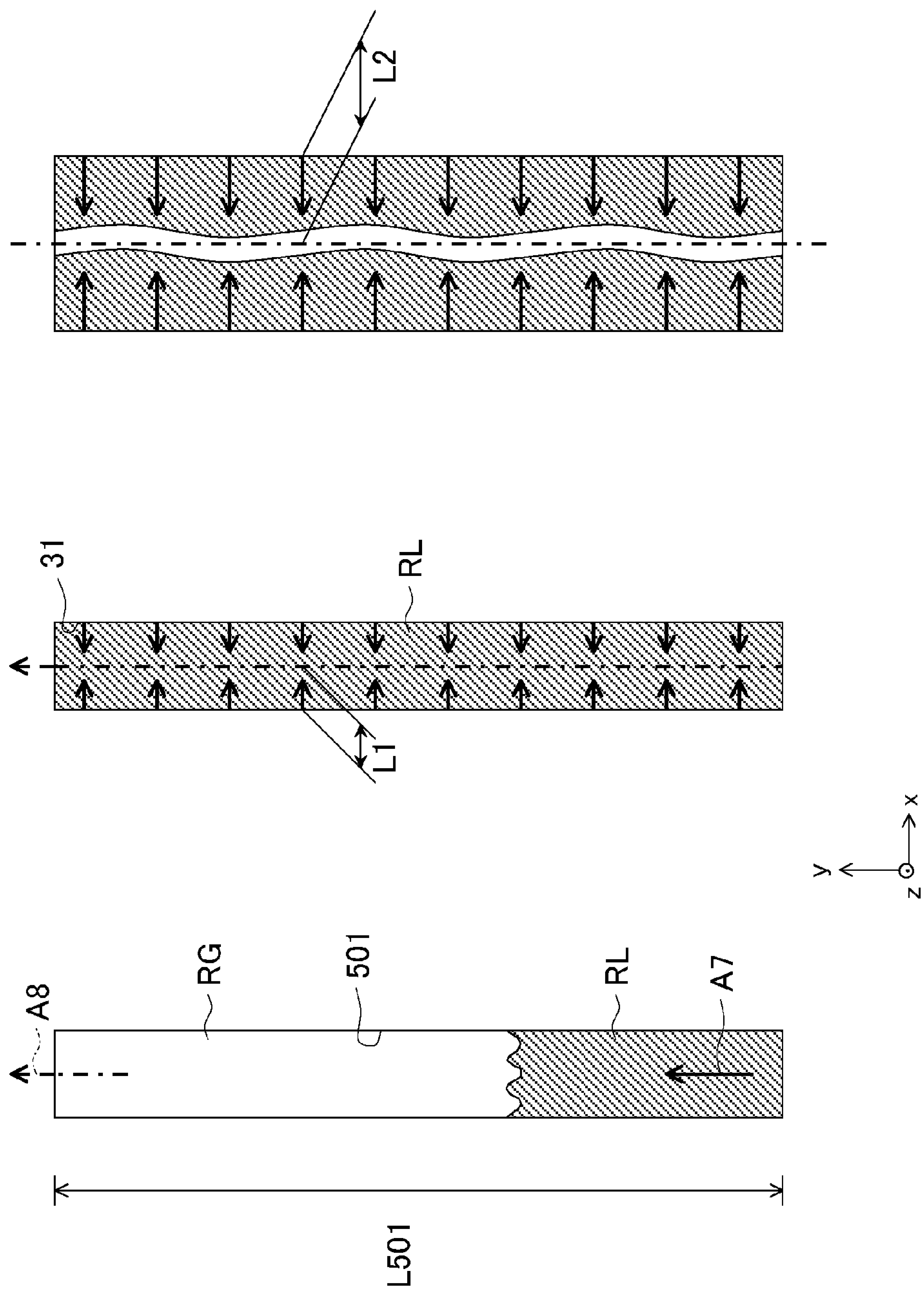


FIG. 5A

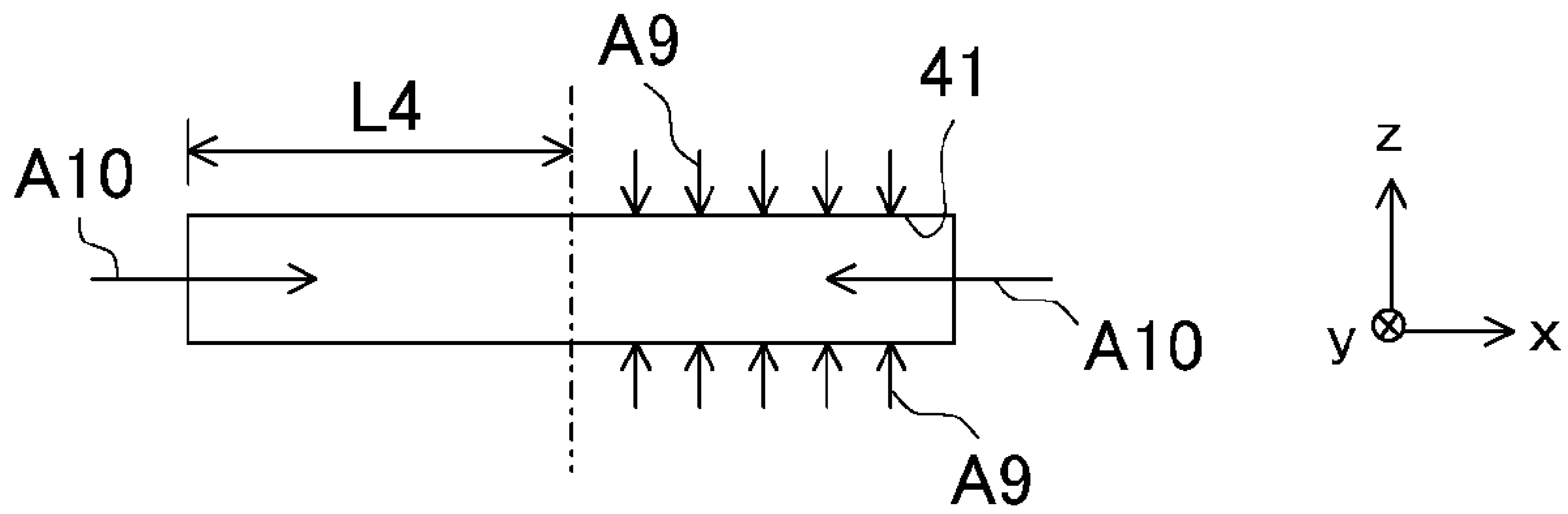


FIG. 5B

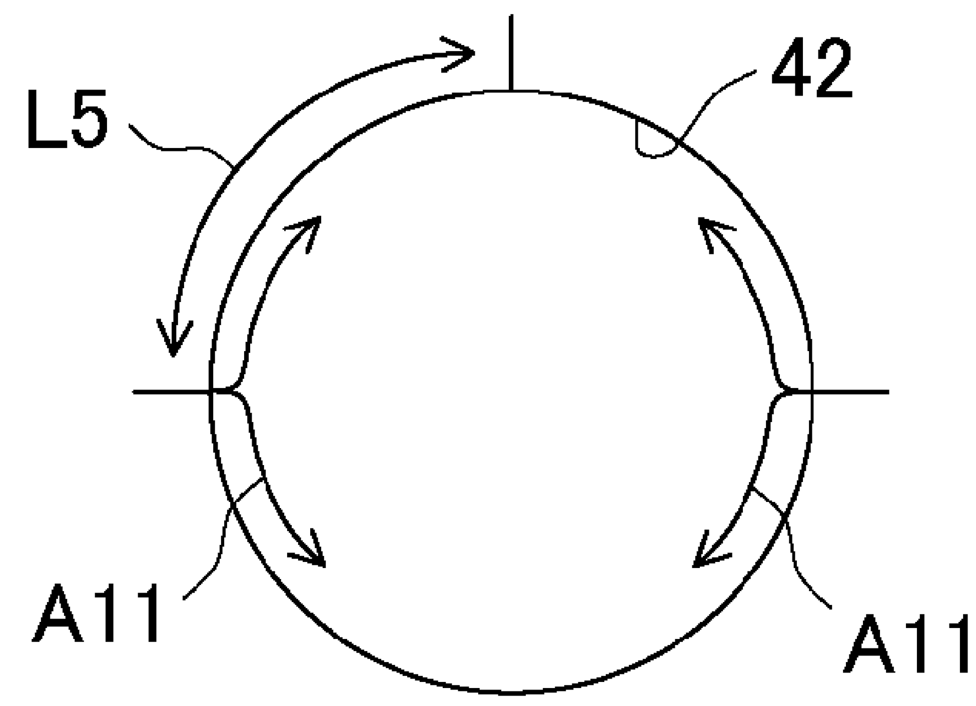


FIG. 5C

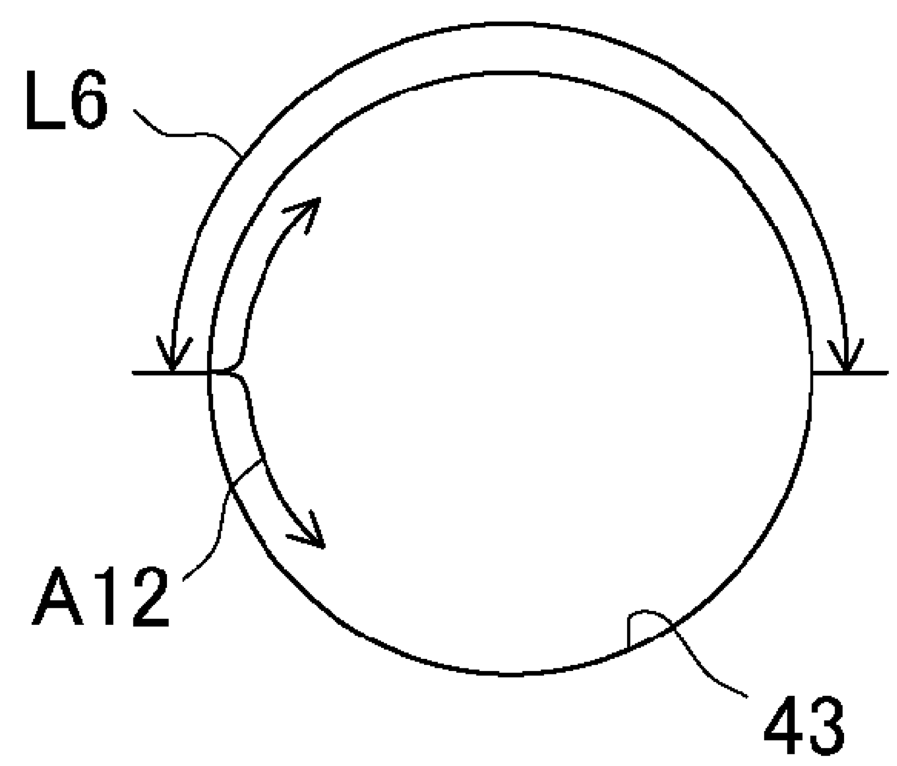


FIG. 5D

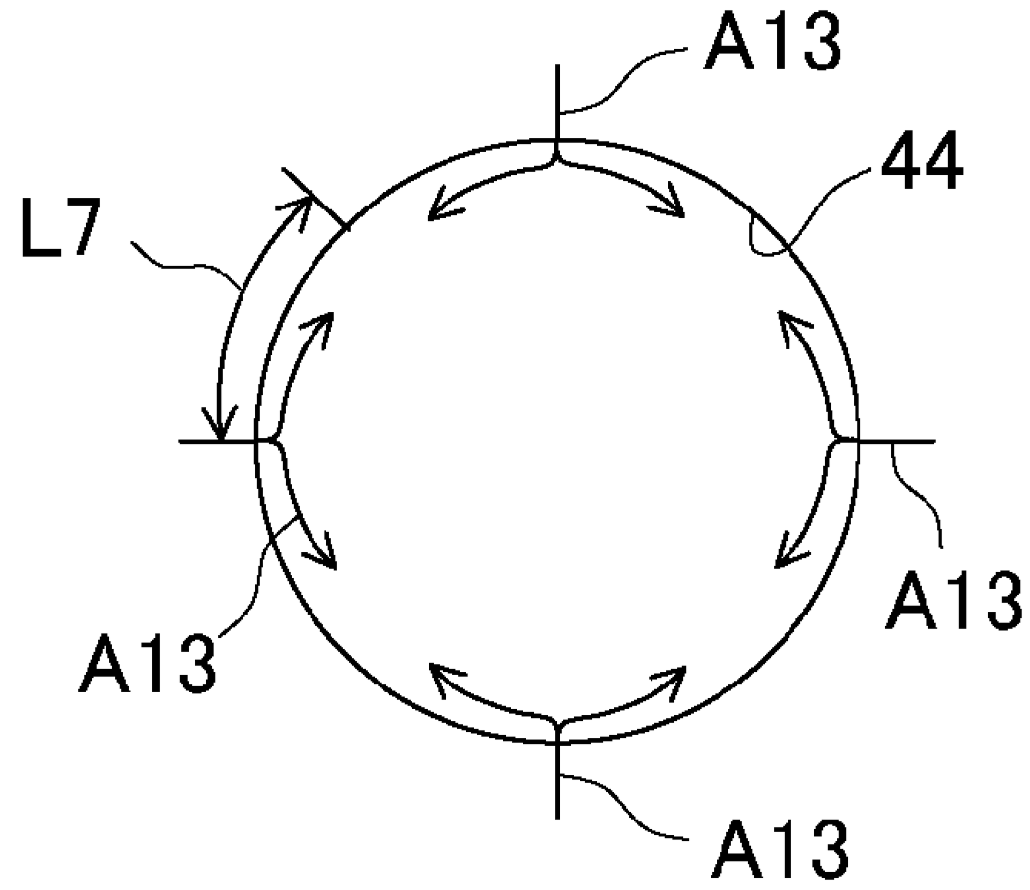


FIG. 6A

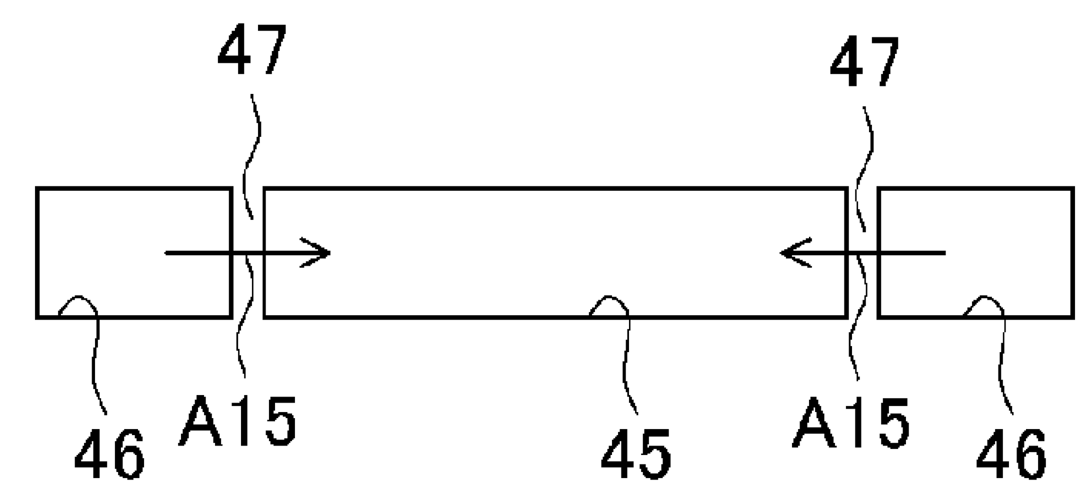


FIG. 6B

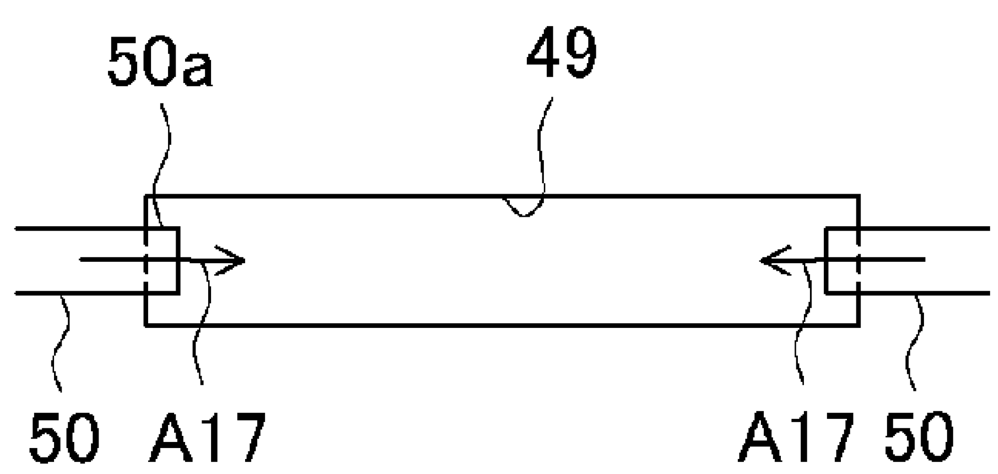


FIG. 6C

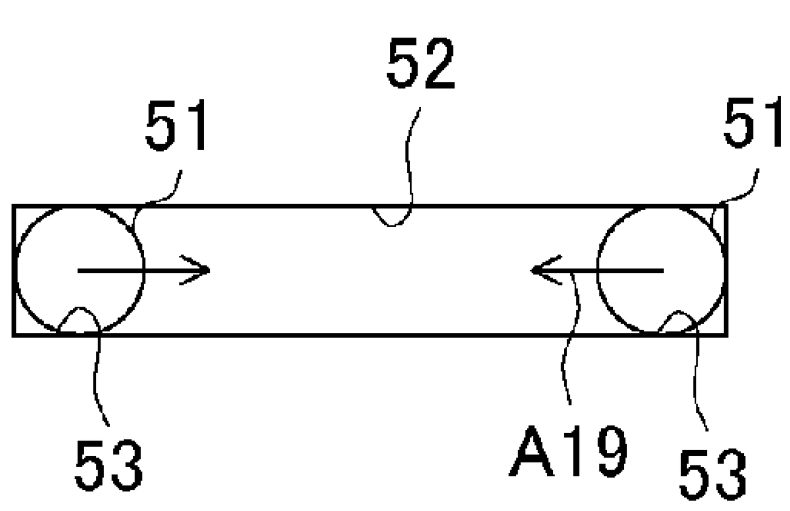


FIG. 6D

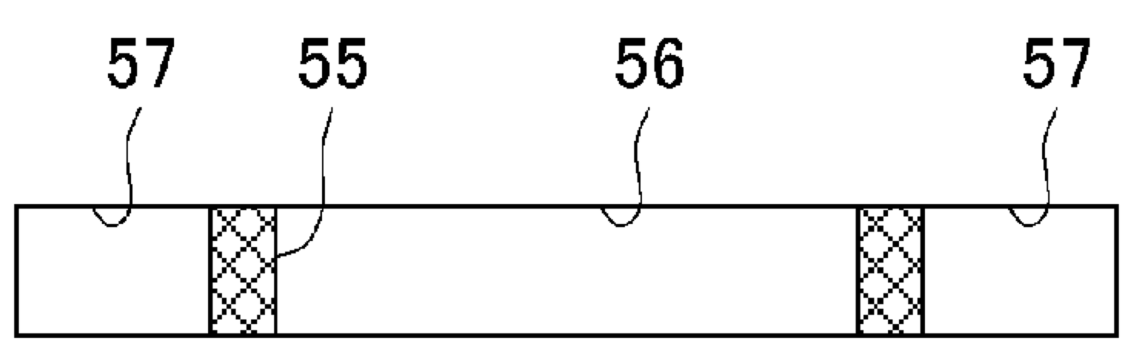


FIG. 6E

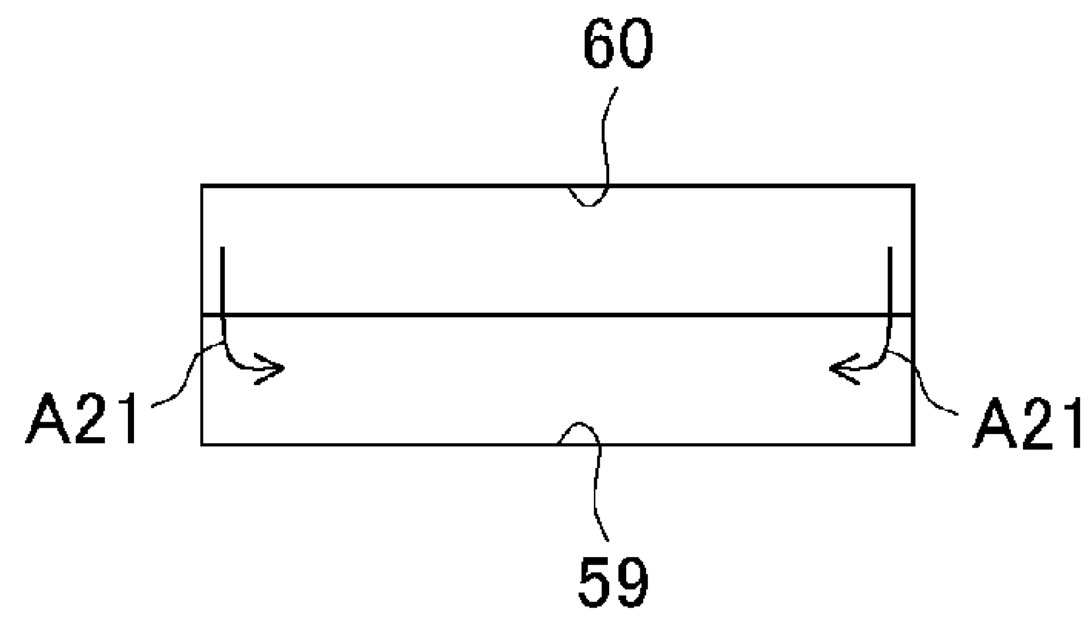


FIG. 6F

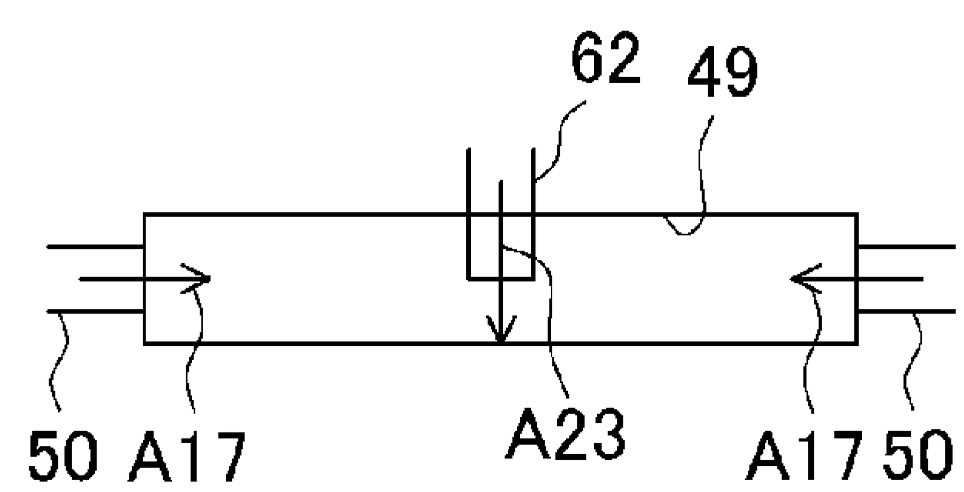
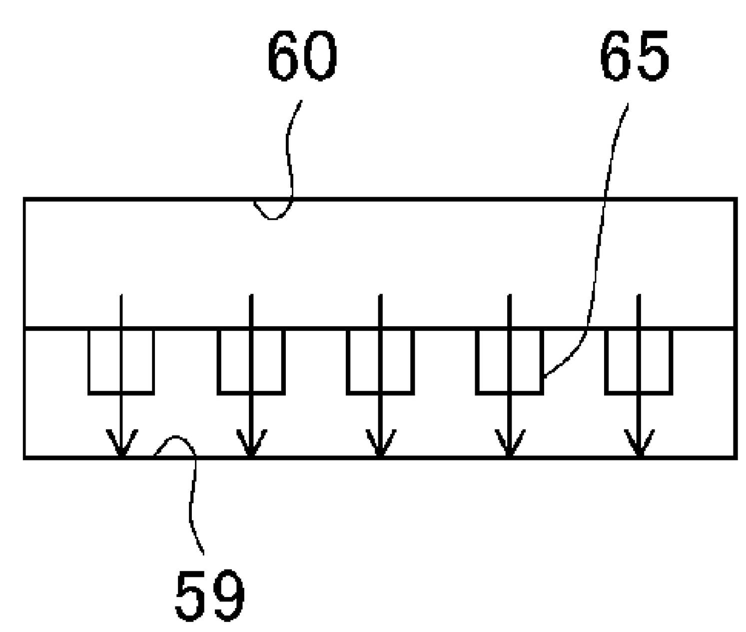


FIG. 6G



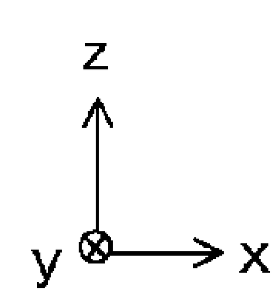


FIG. 7A

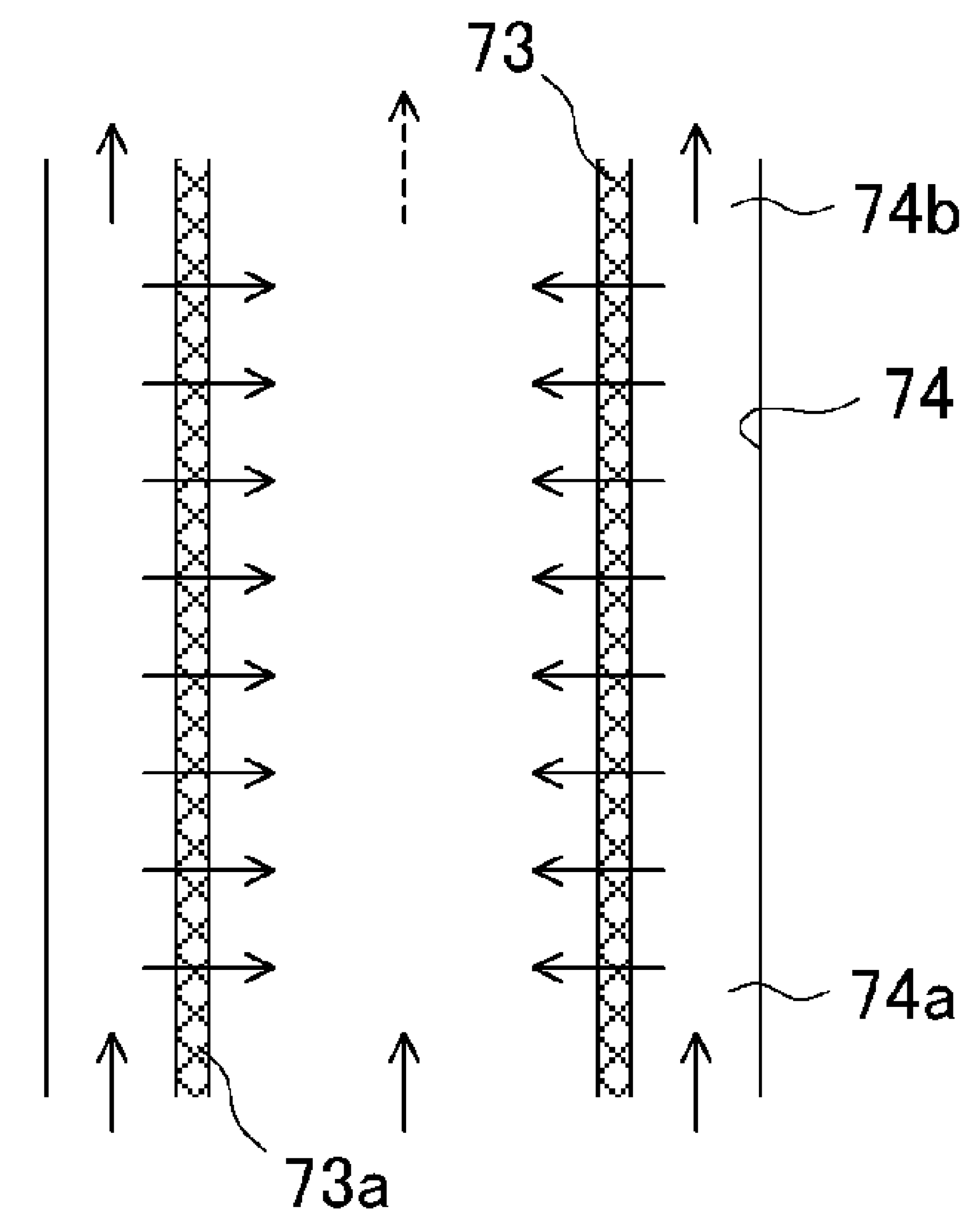


FIG. 7C

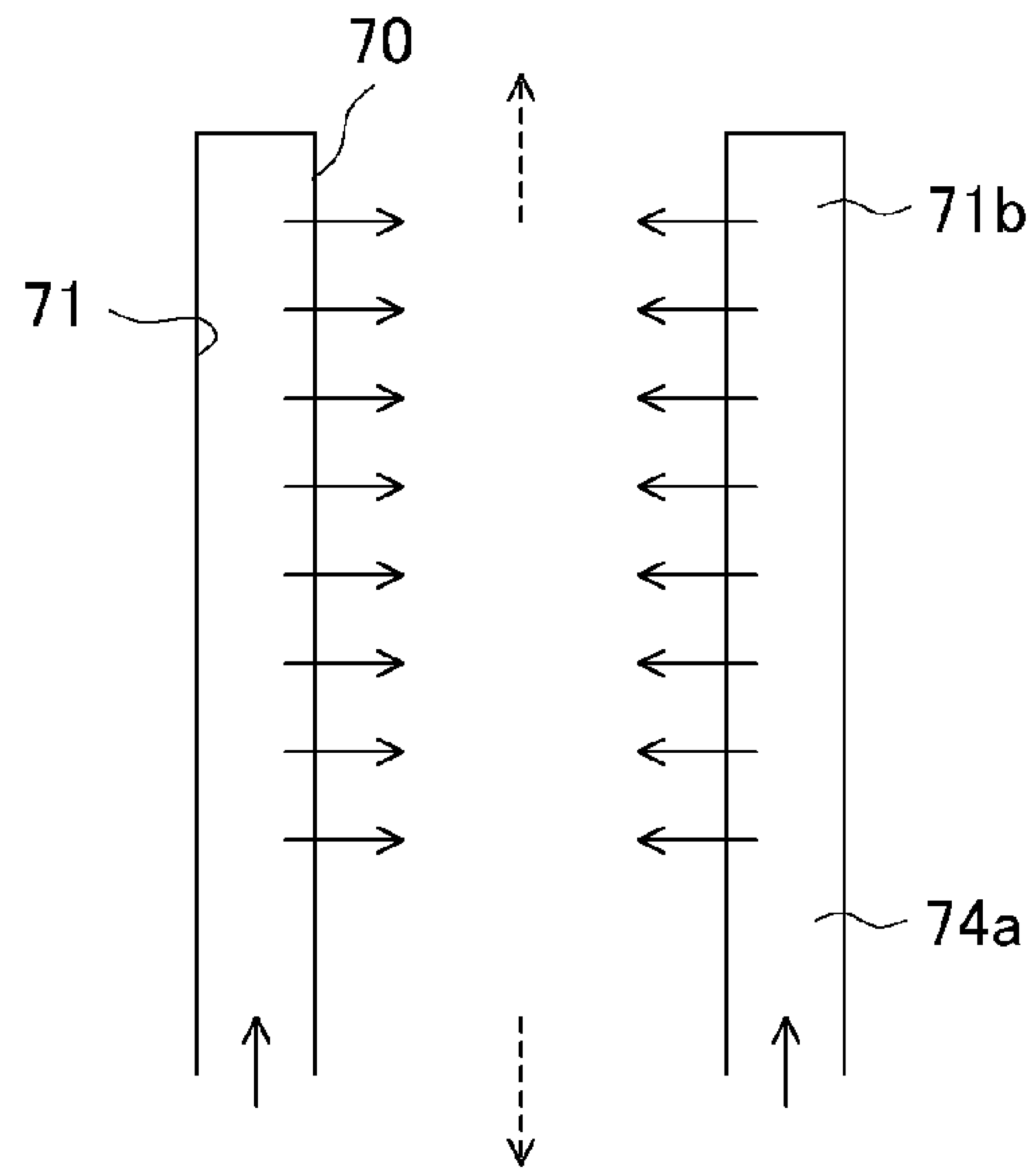


FIG. 7B

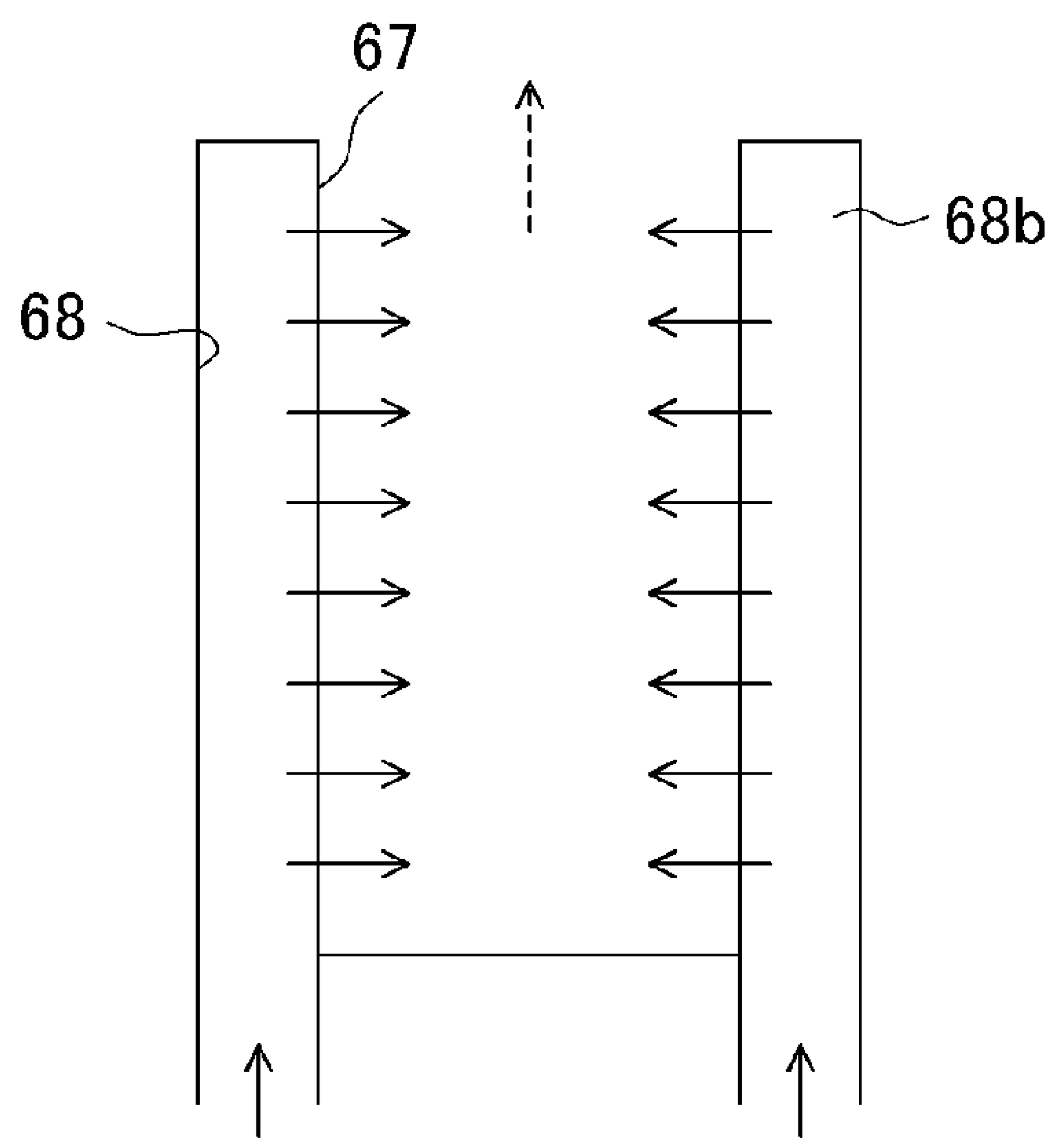


FIG. 7D

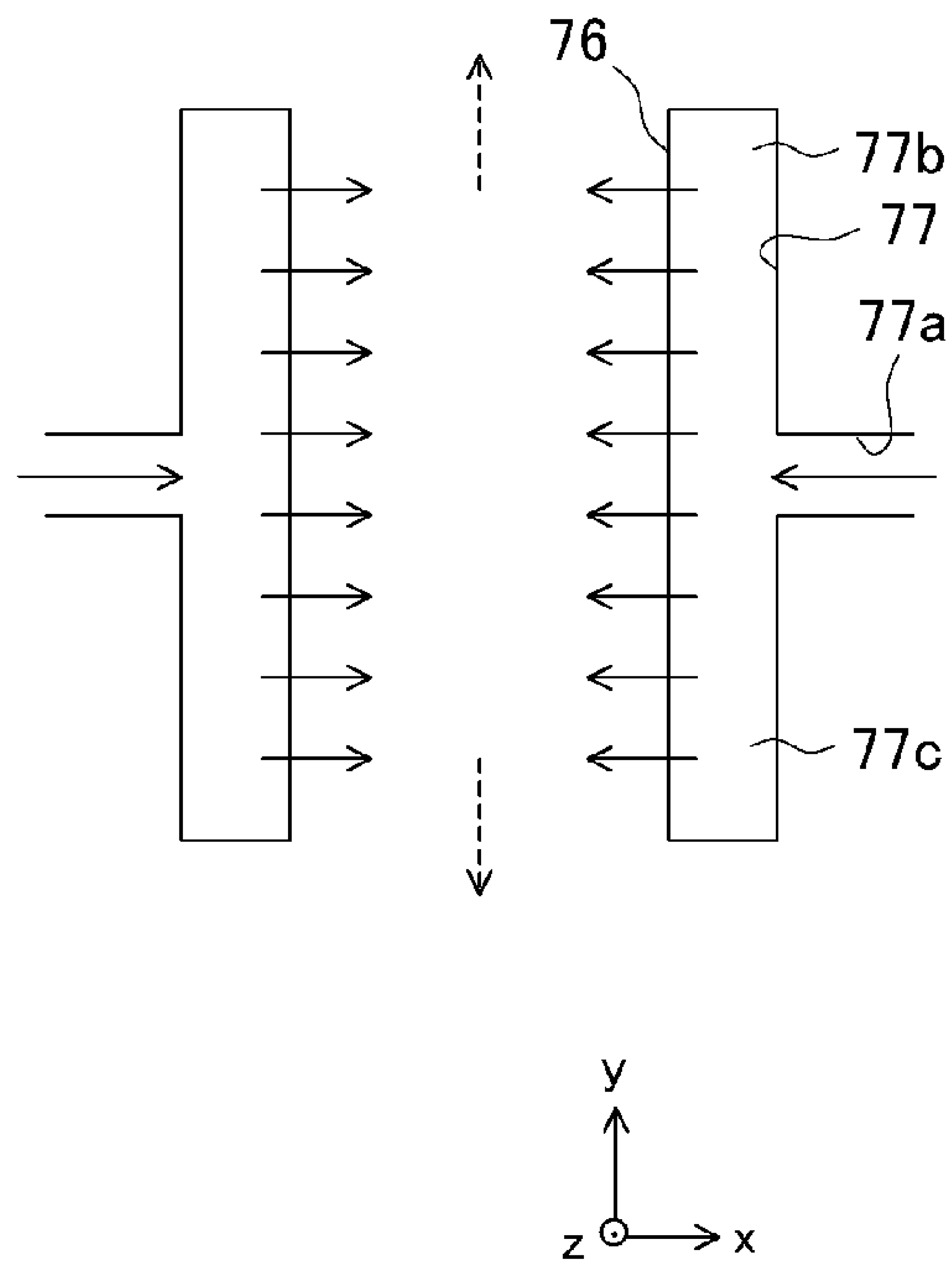


FIG. 8A

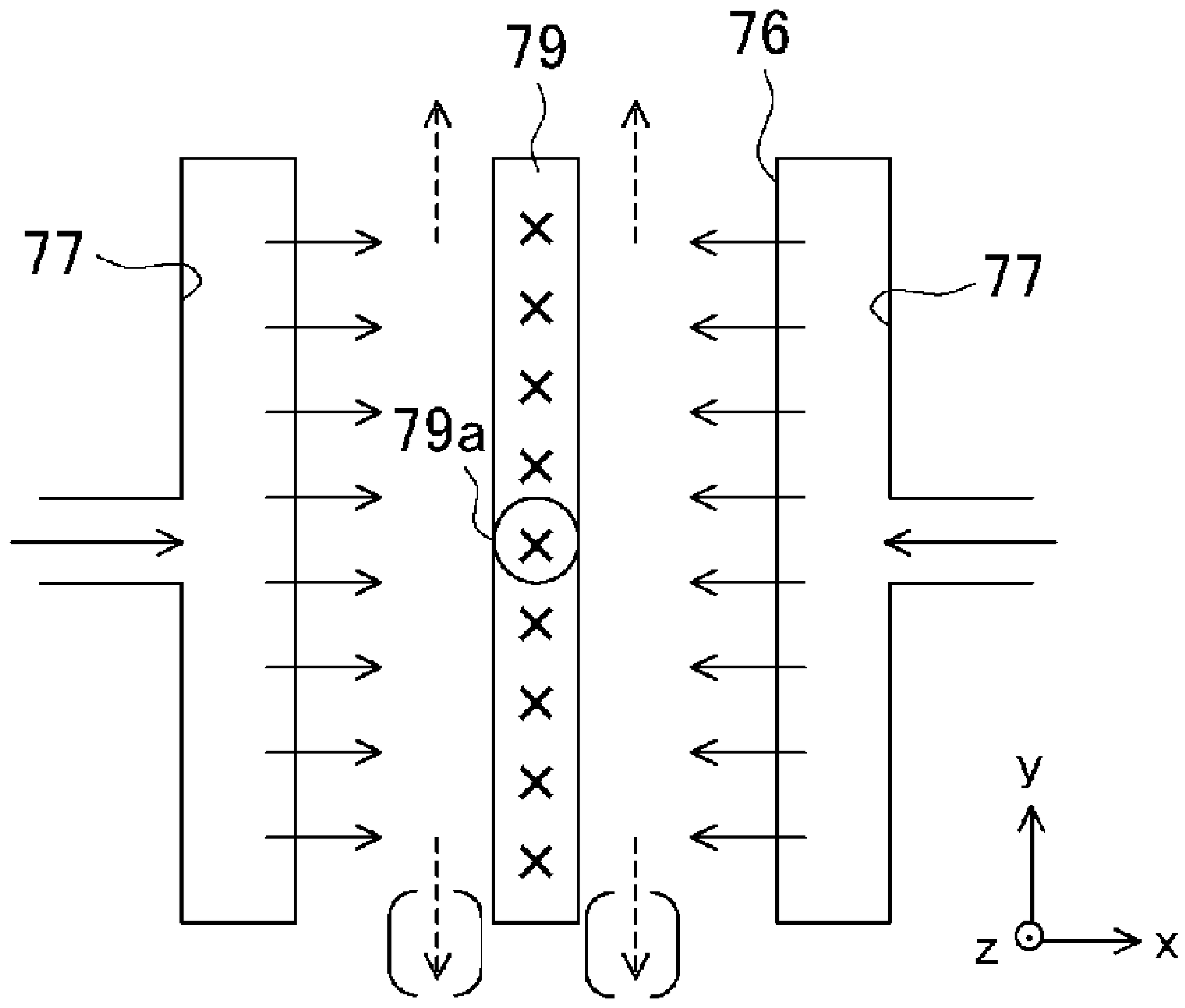


FIG. 8D

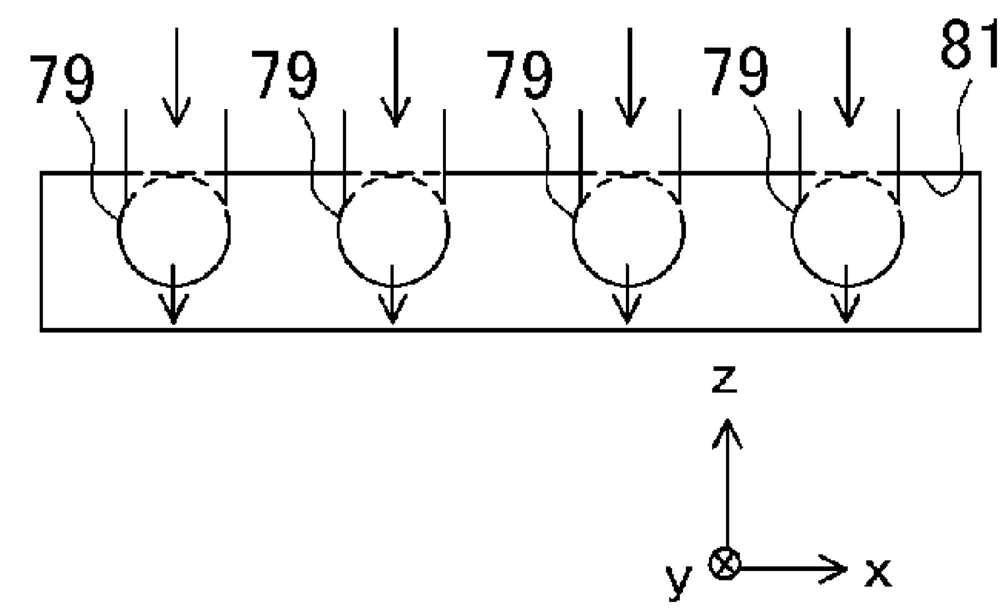


FIG. 8B

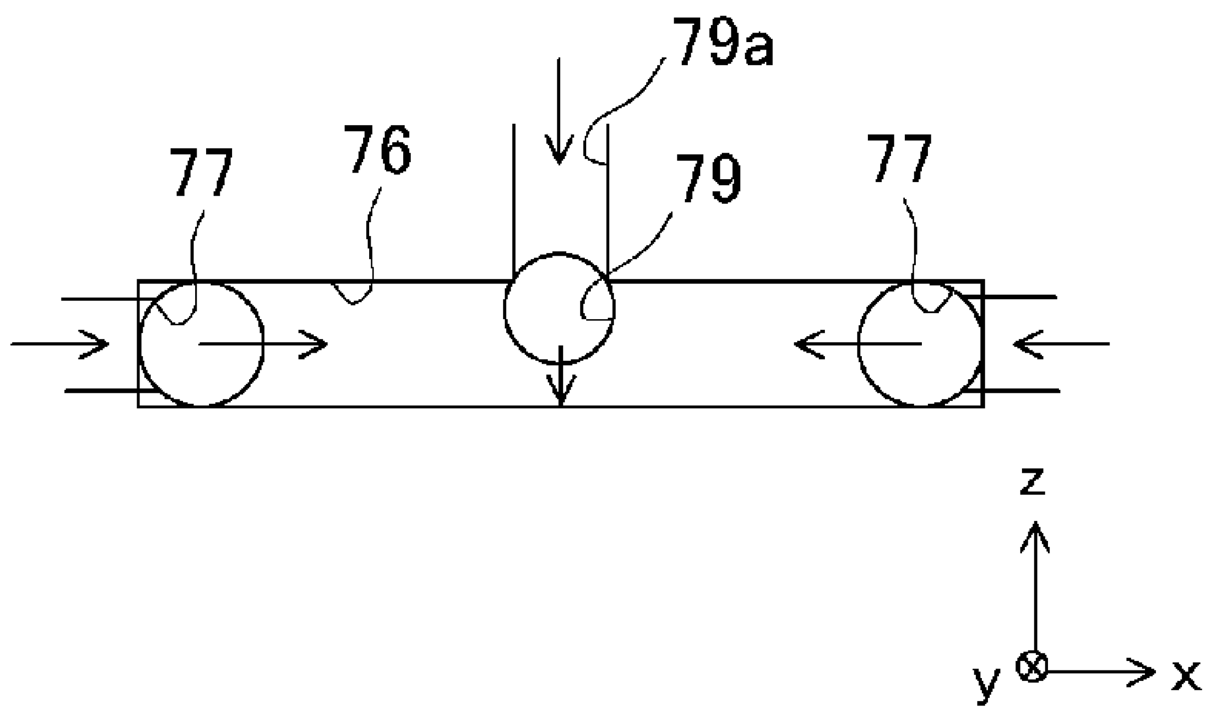


FIG. 8E

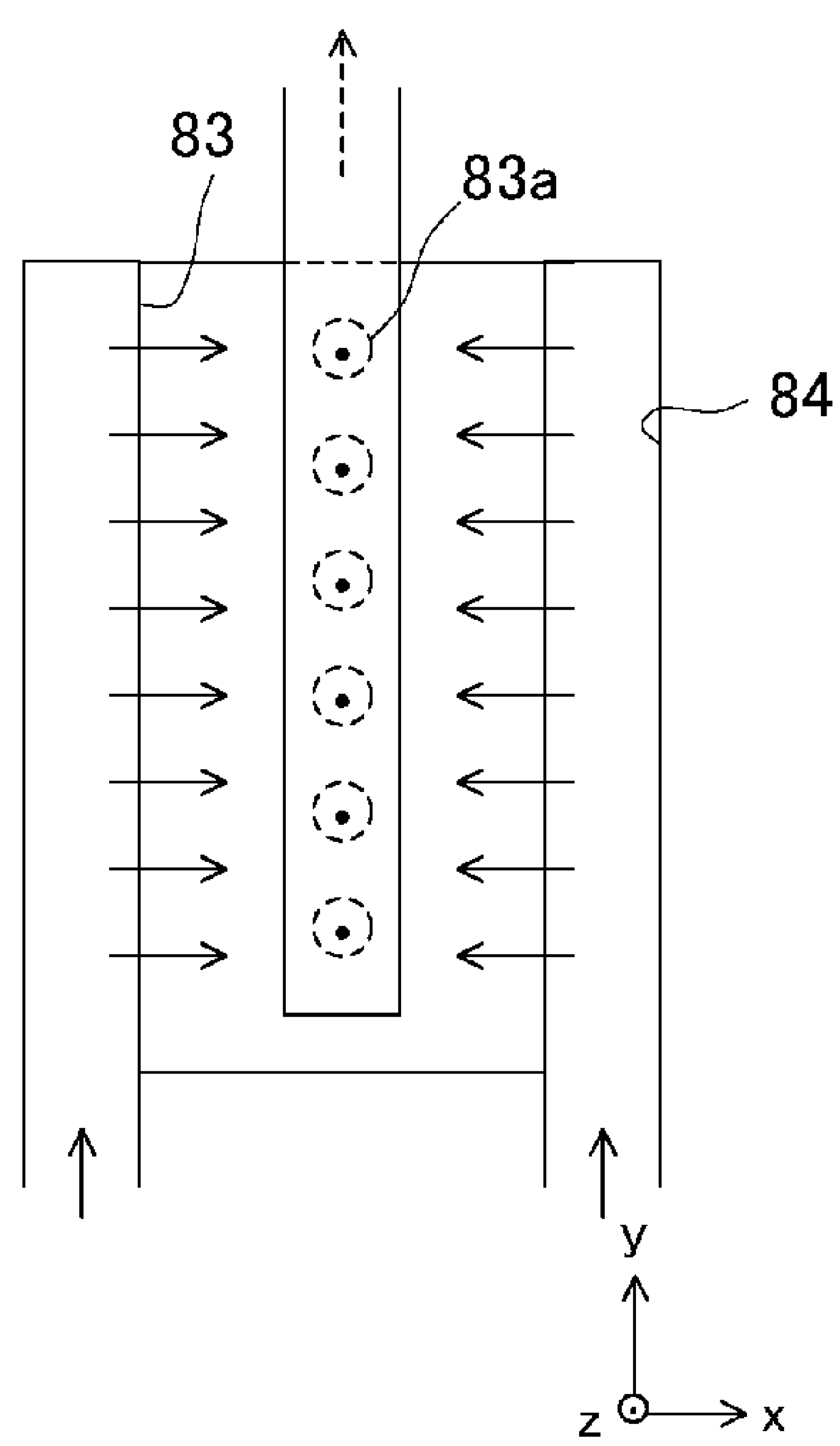


FIG. 8C

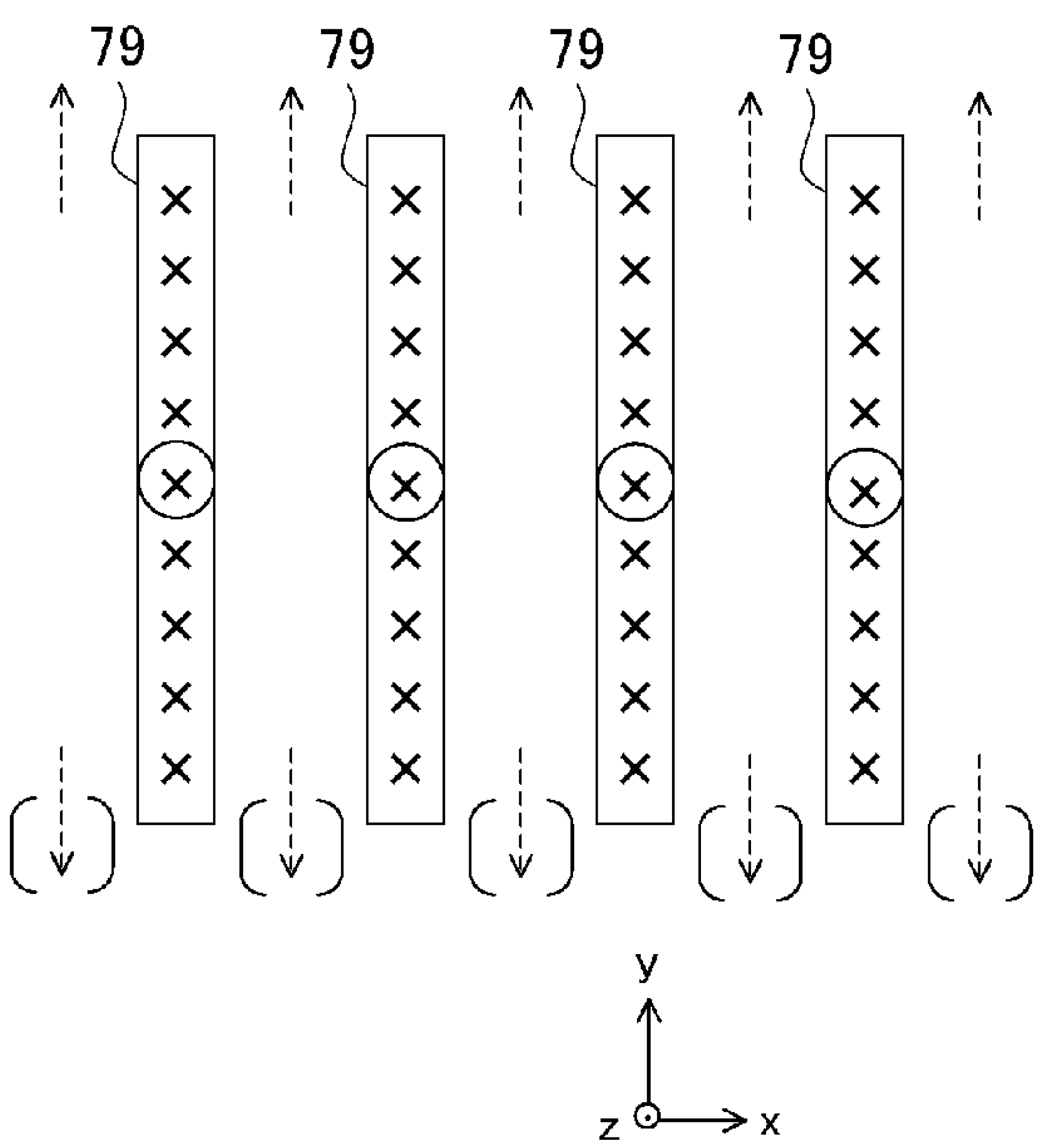


FIG. 8F

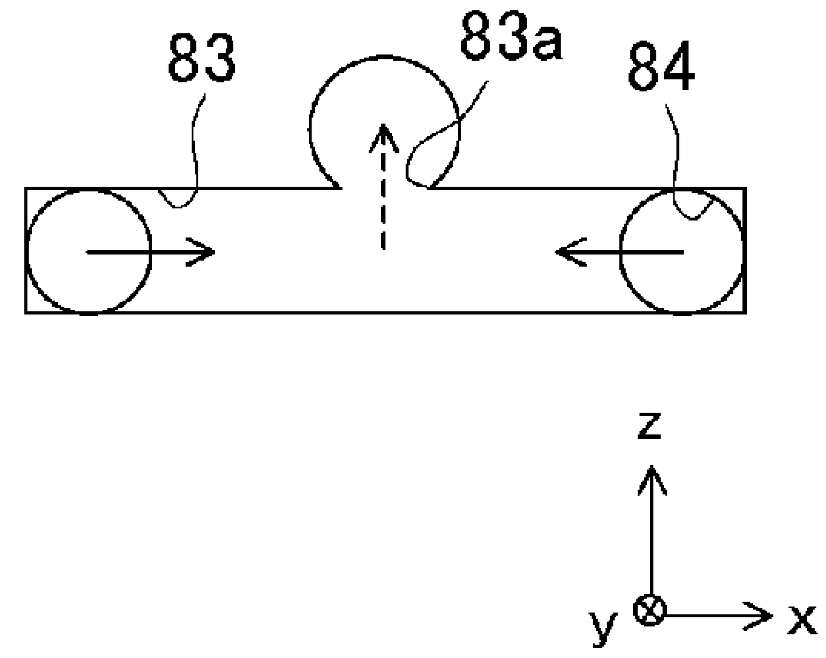


FIG. 9A

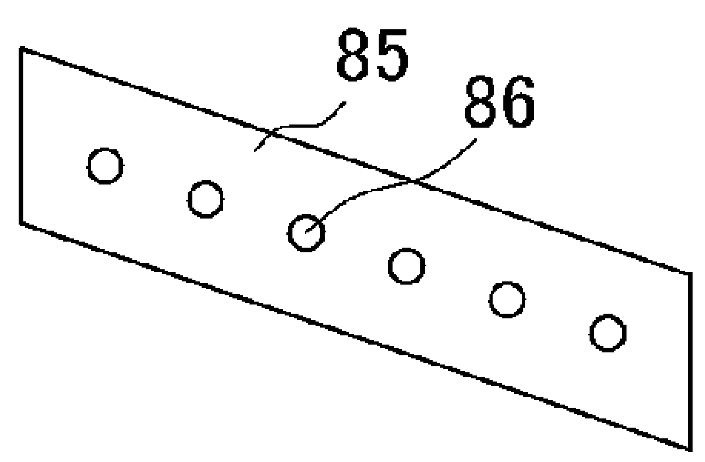


FIG. 9B

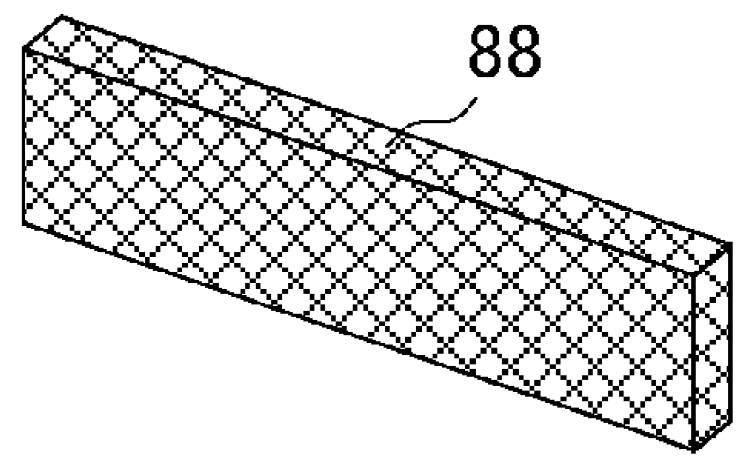


FIG. 9C

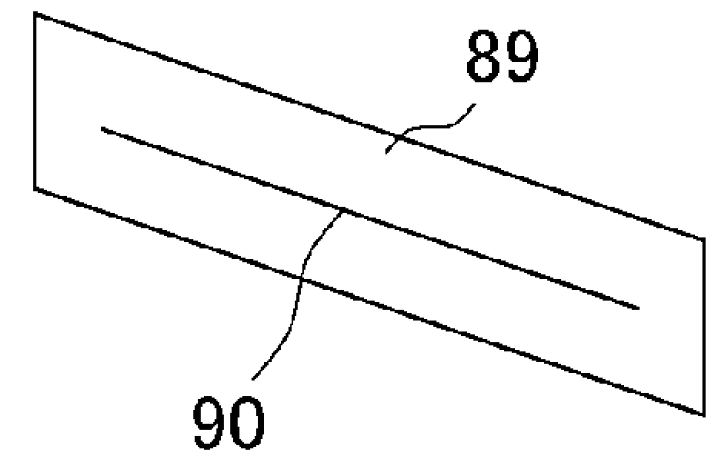


FIG. 9D

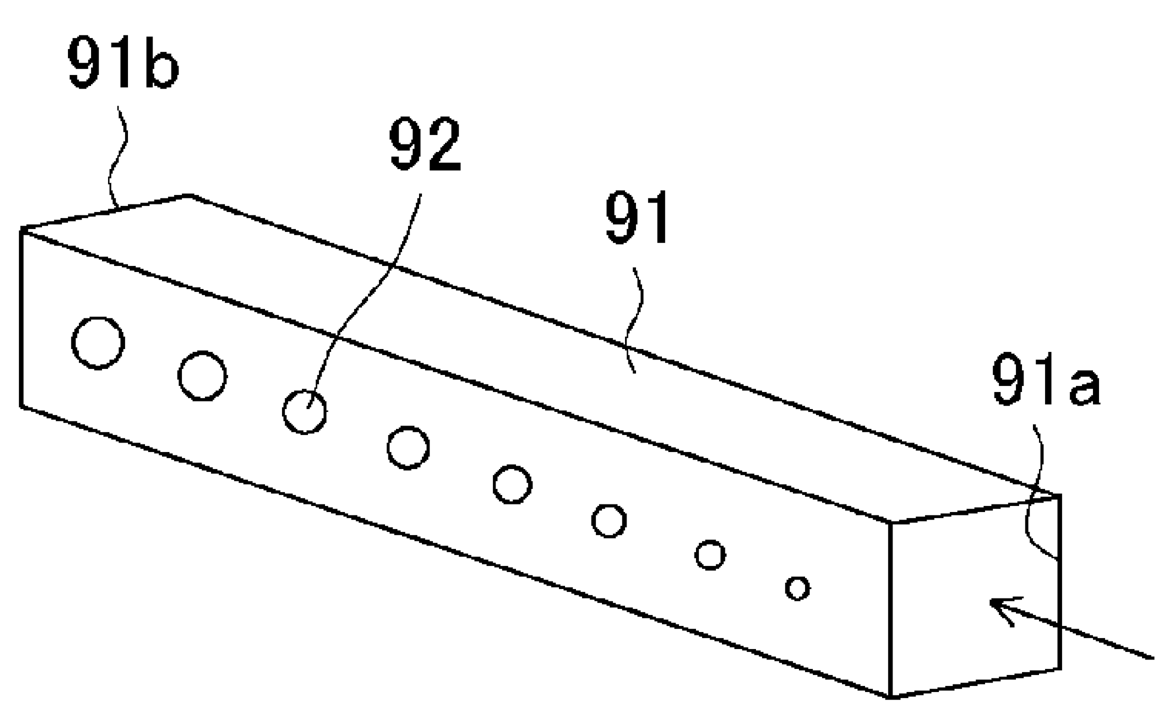


FIG. 9E

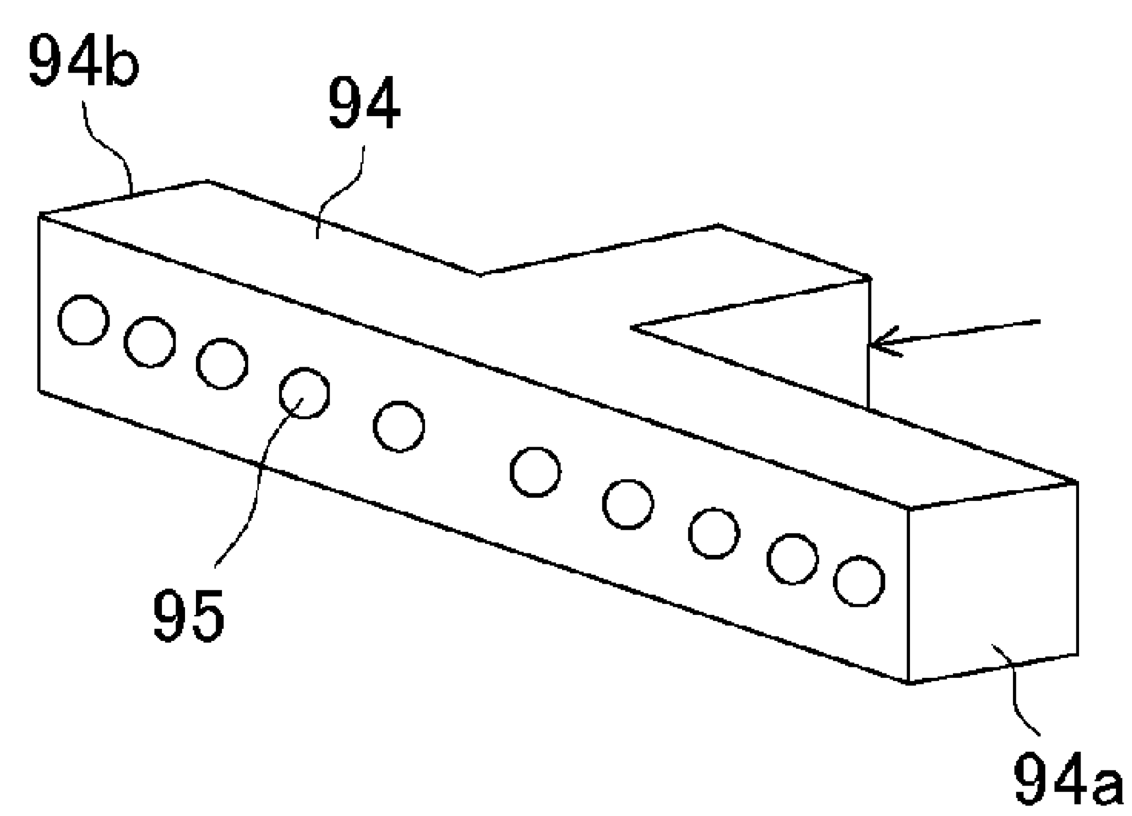


FIG. 10A

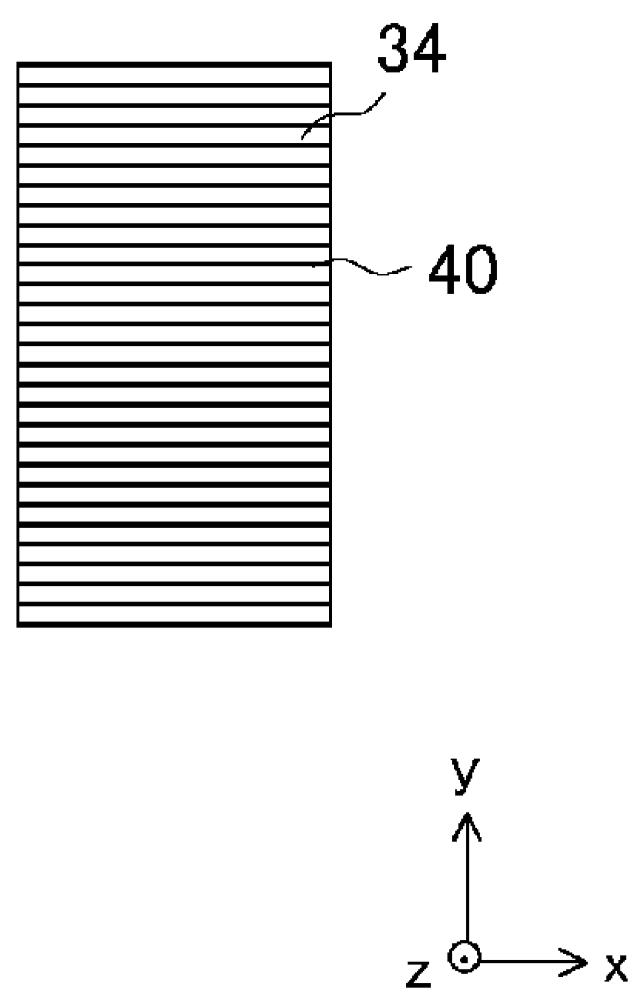


FIG. 10B

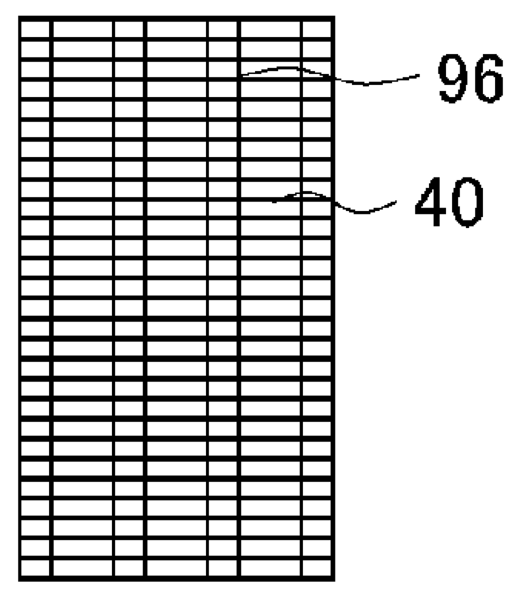


FIG. 10C

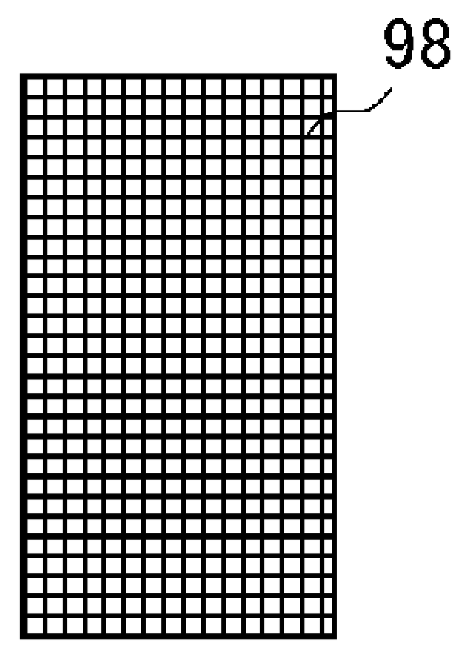


FIG. 10D

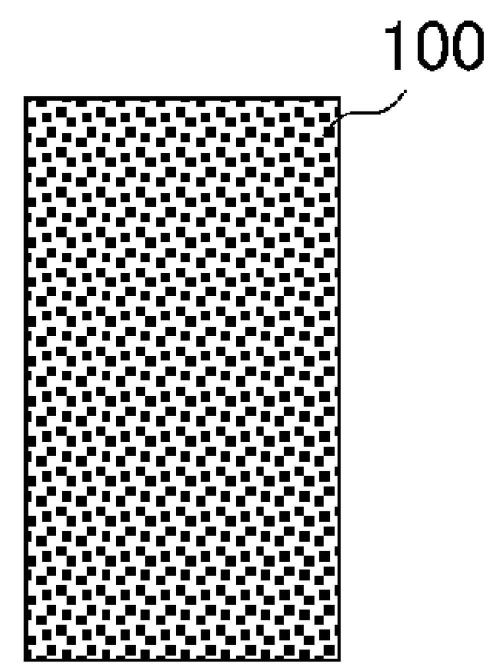


FIG. 10E

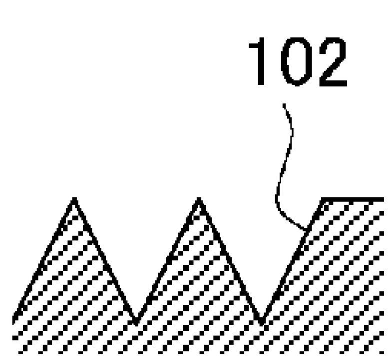


FIG. 10F

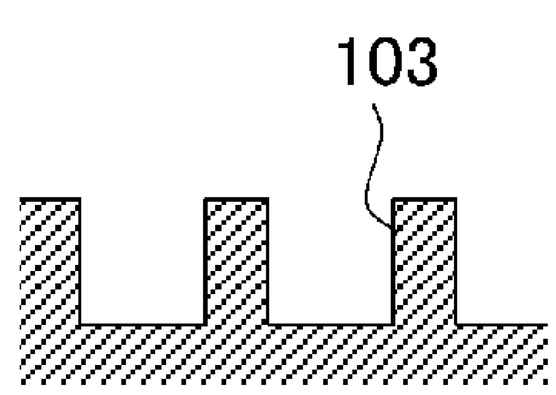


FIG. 11A

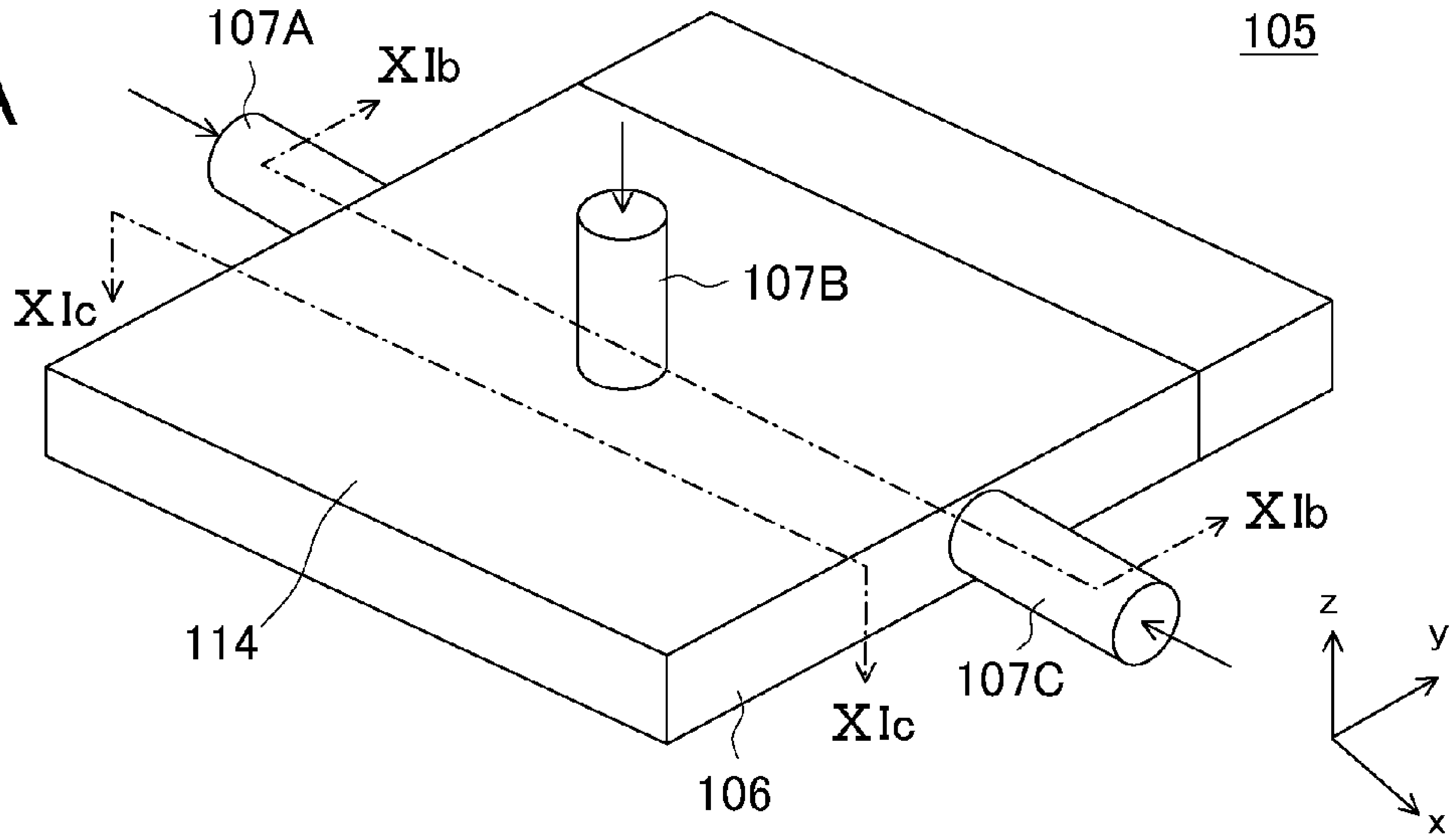


FIG. 11B

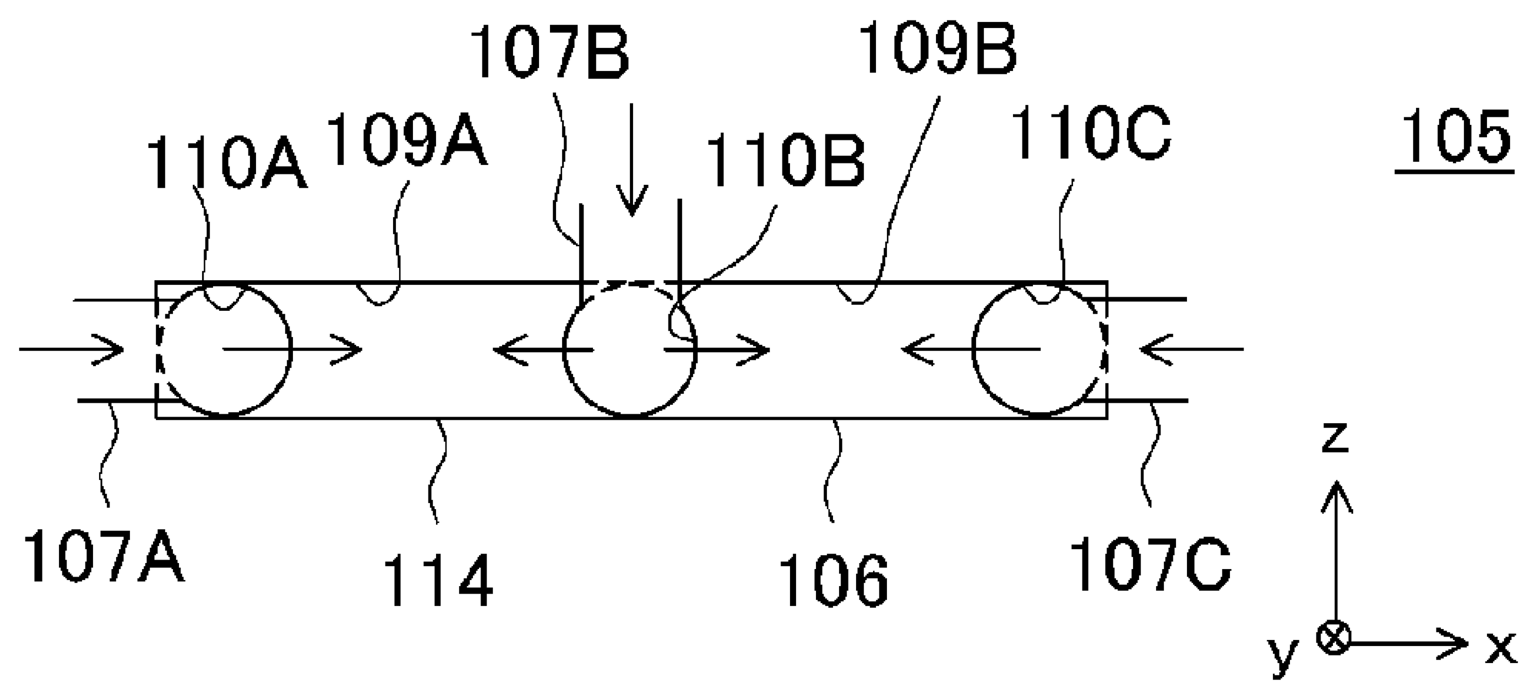


FIG. 11C

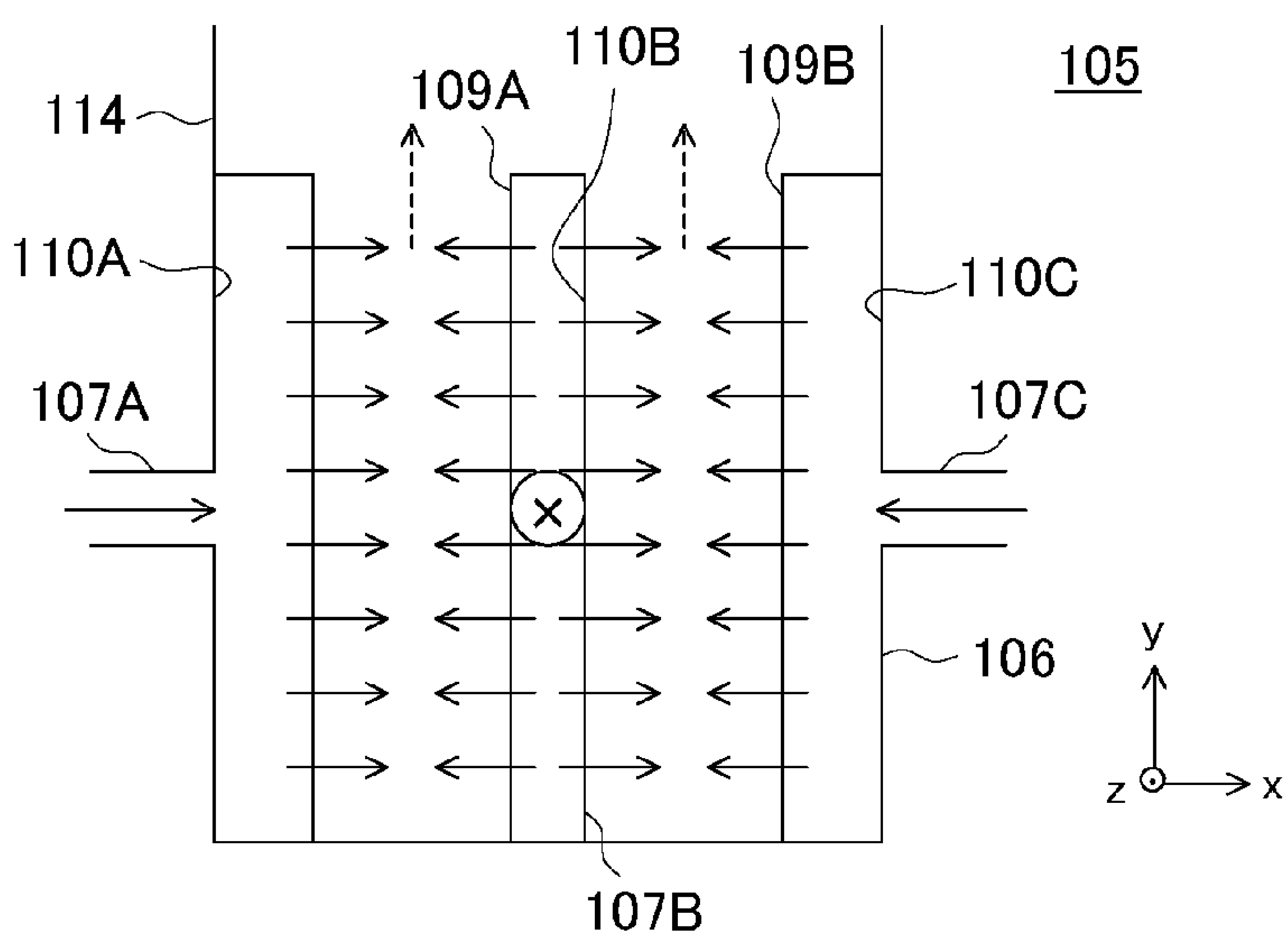


FIG. 12A

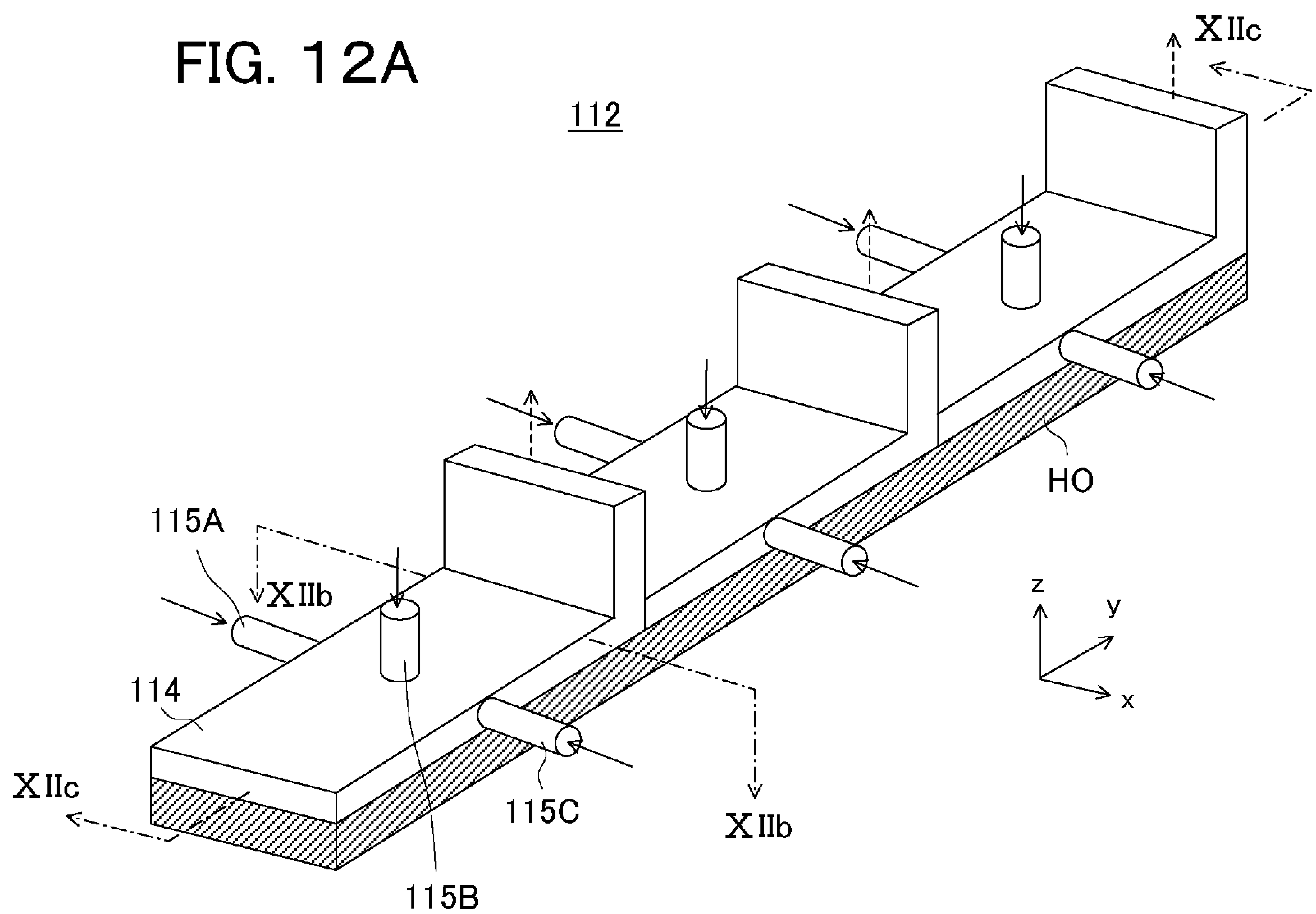


FIG. 12B

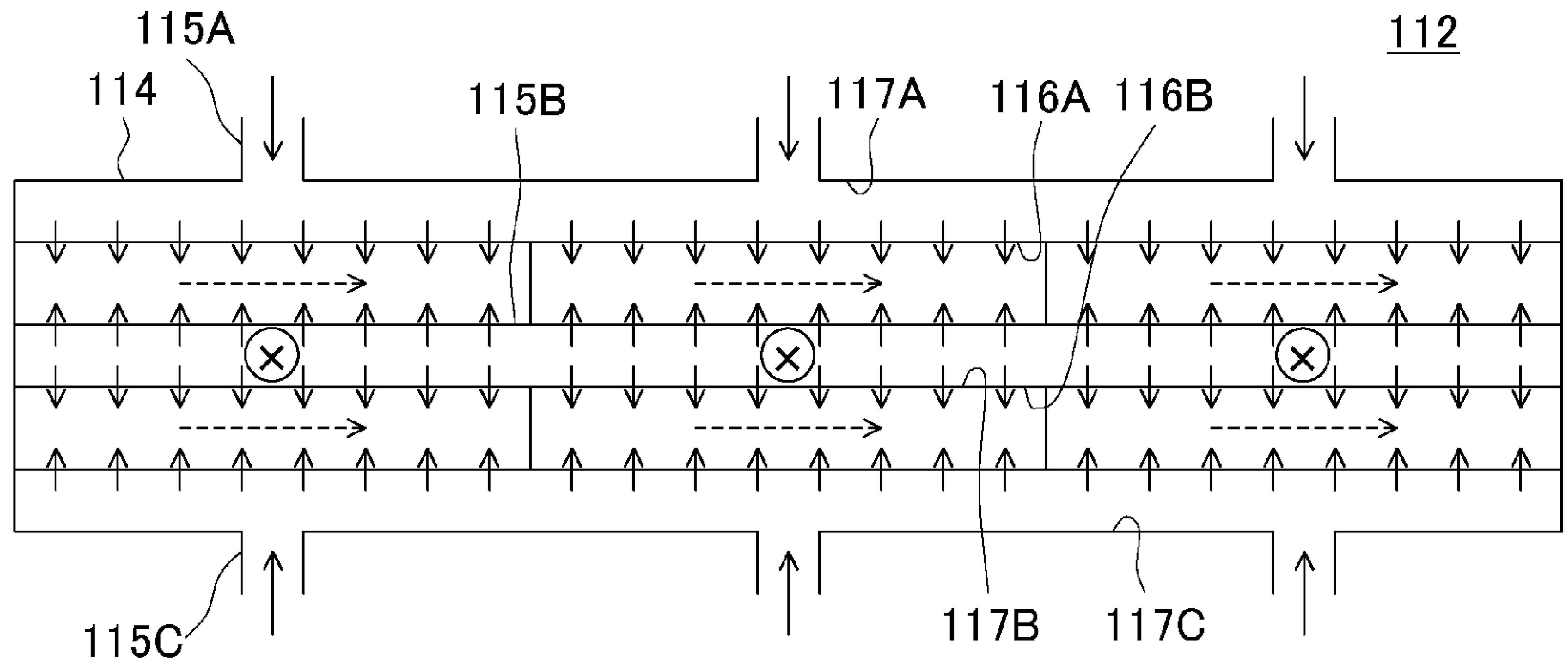


FIG. 12C

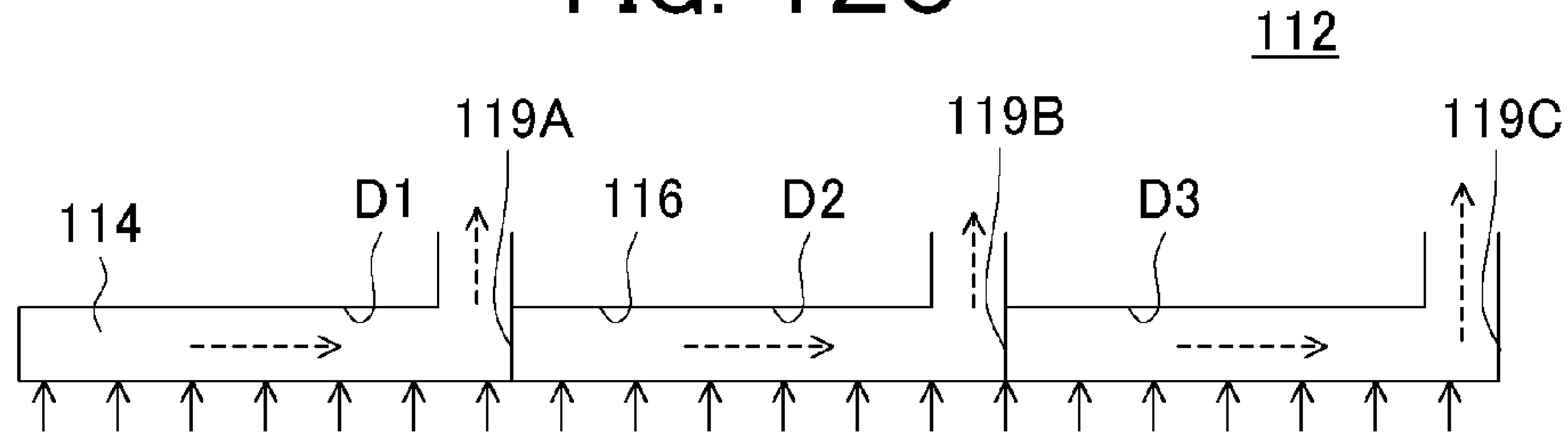


FIG. 13

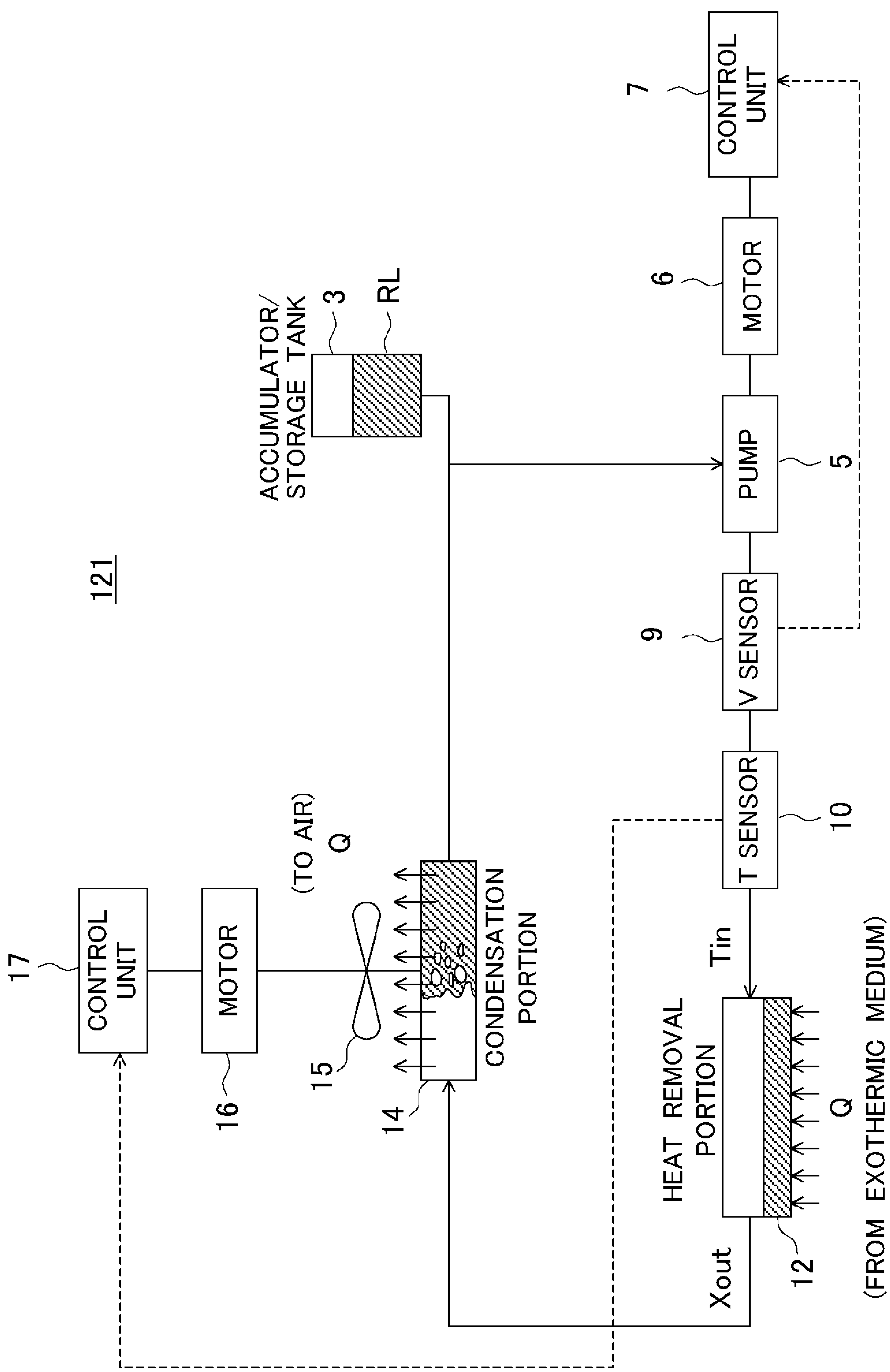
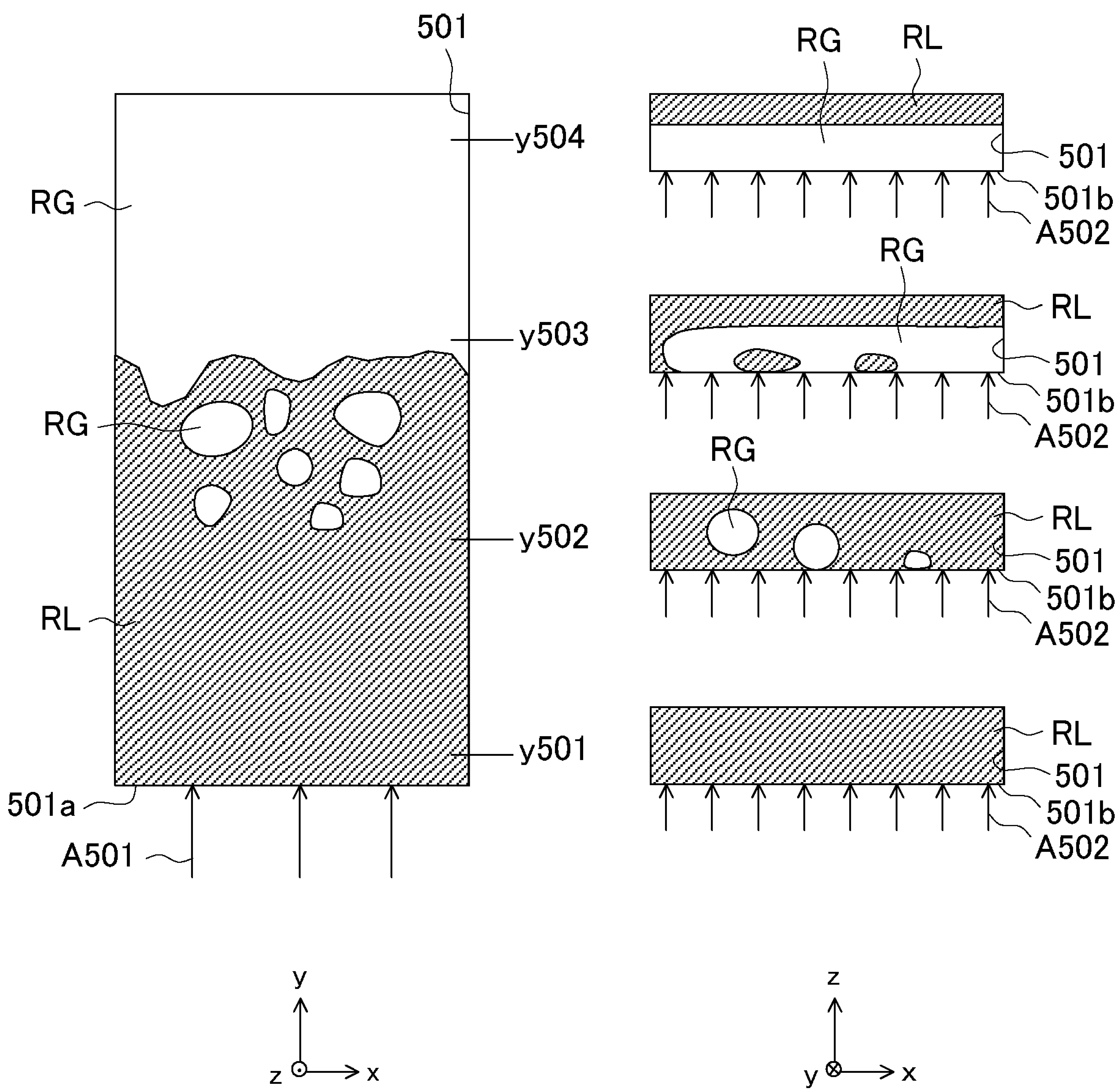

121
ACCUMULATOR/
STORAGE TANK
3
RL
CONTROL
UNIT
7
MOTOR
6
PUMP
5
V SENSOR
9
T SENSOR
10
Tin
HEAT REMOVAL
PORTION
12
Q
(FROM EXOTHERMIC MEDIUM)
Xout
CONDENSATION
PORTION
14
(TO AIR)
Q
15
MOTOR
16
CONTROL
UNIT
17

FIG. 14



501
y504
RG
y503
RG
y502
RL
y501
501a
A501
RG
RL
501
501b
A502
RG
RL
501
501b
A502
RG
RL
501
501b
A502
RL
501
501b
A502
y
z
x
z
y
x

FIG. 15A

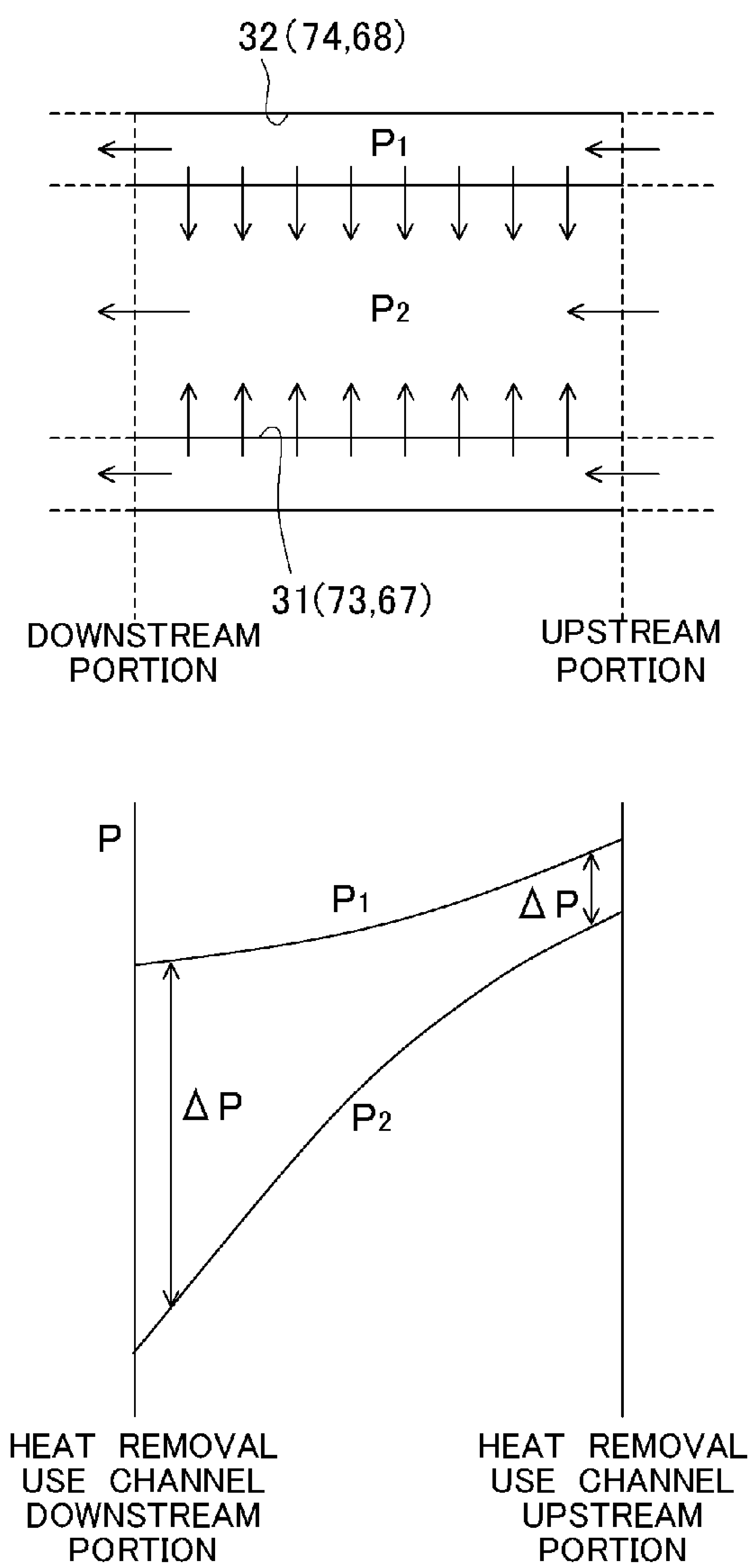


FIG. 15B

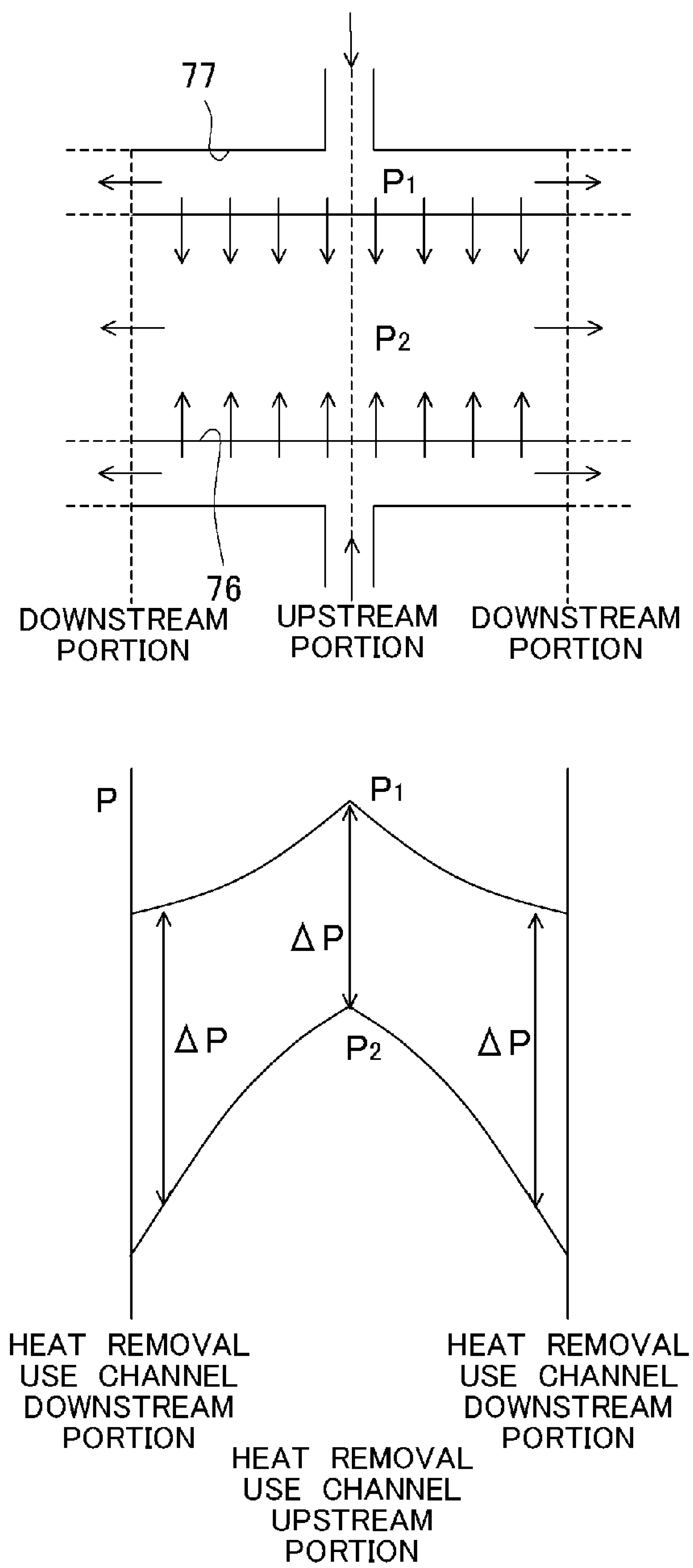


FIG. 16A

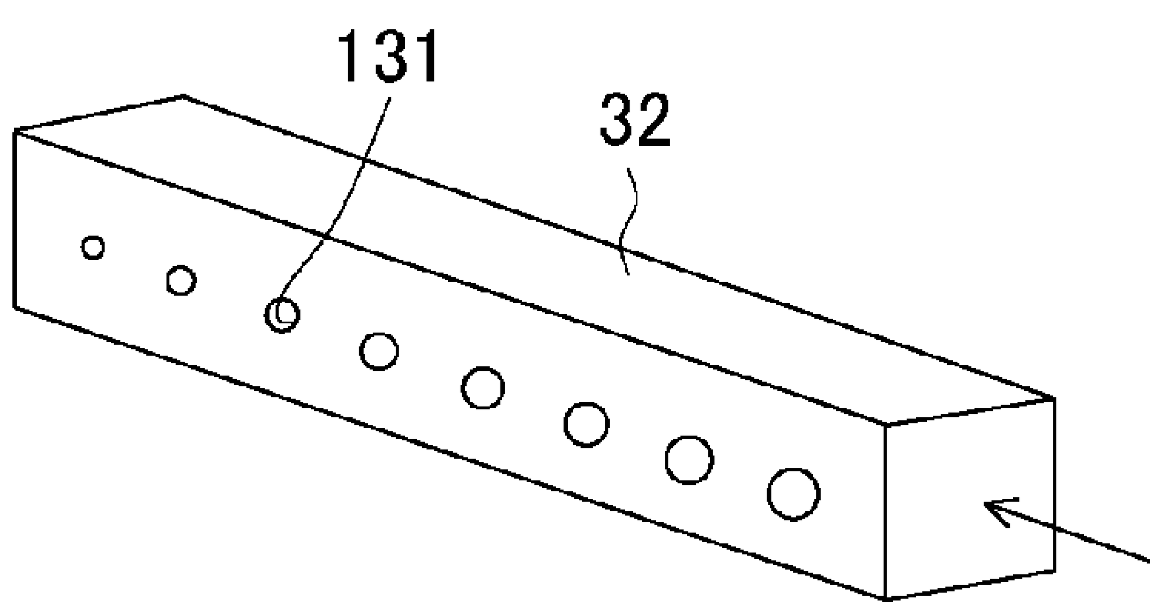


FIG. 16D

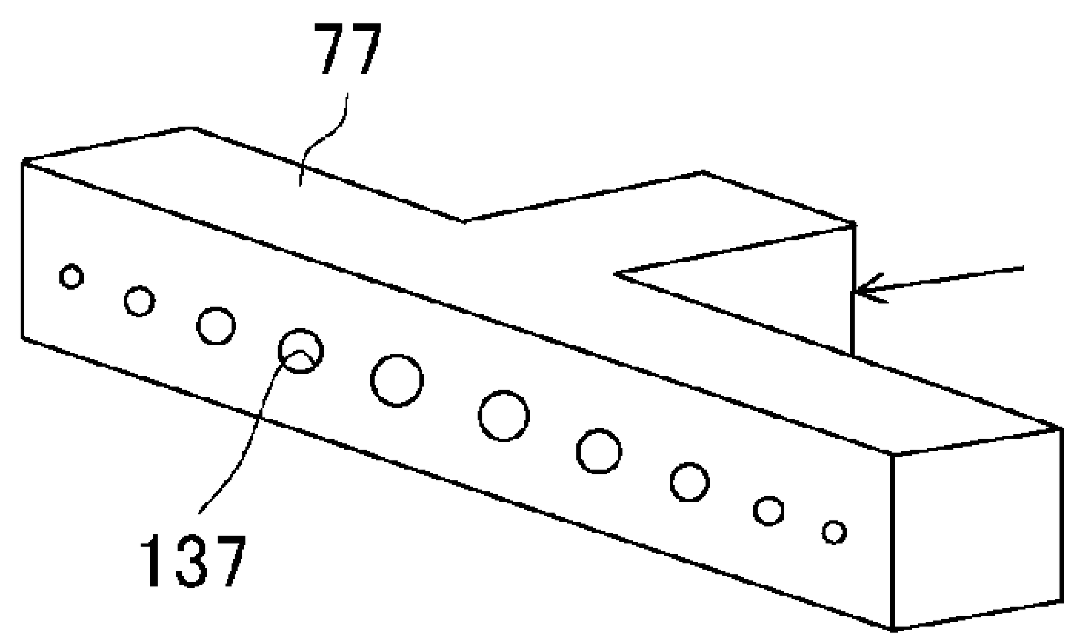


FIG. 16B

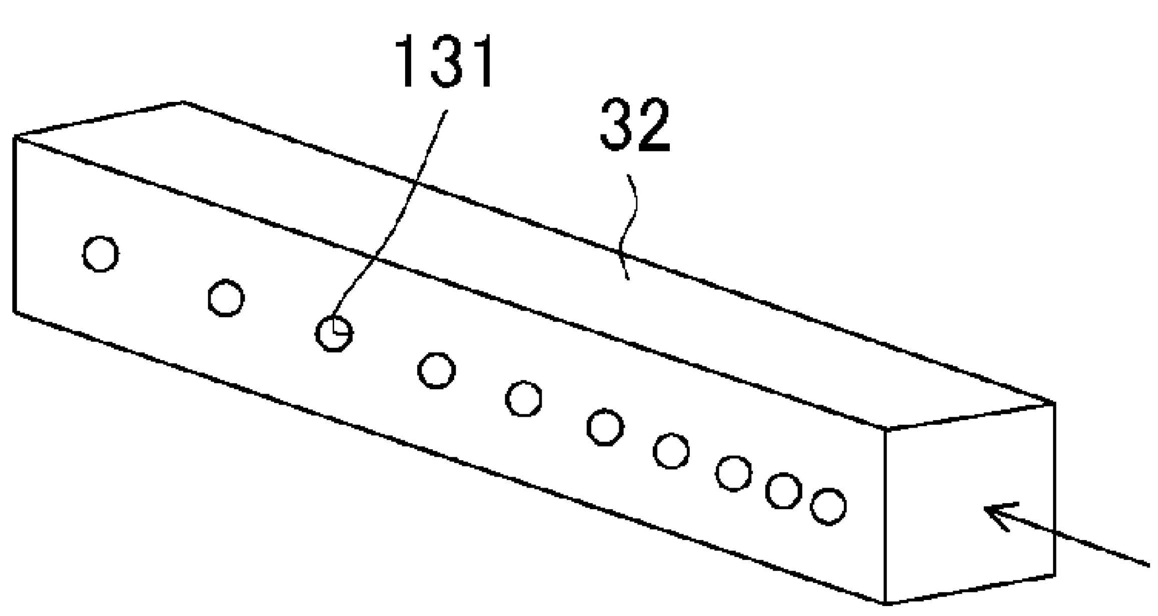


FIG. 16E

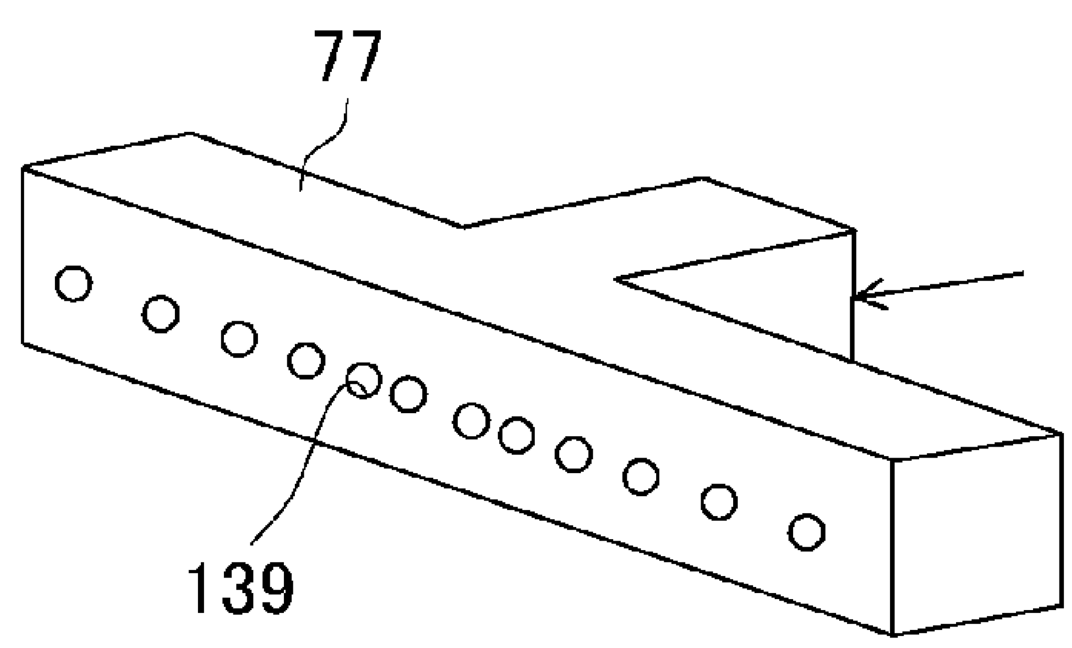


FIG. 16C

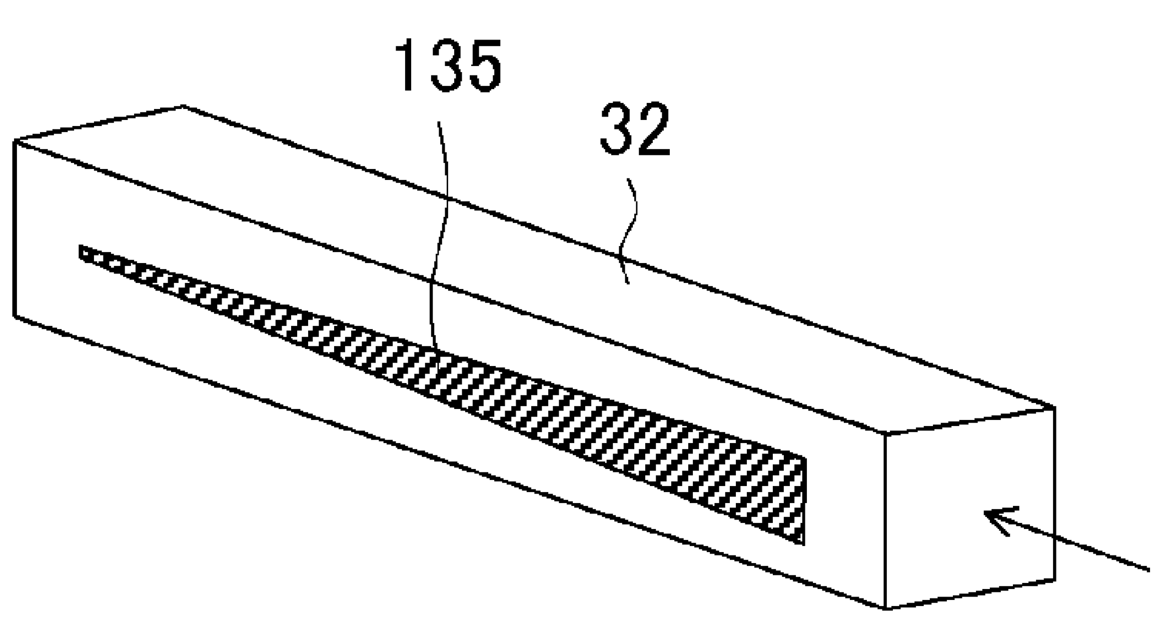


FIG. 16F

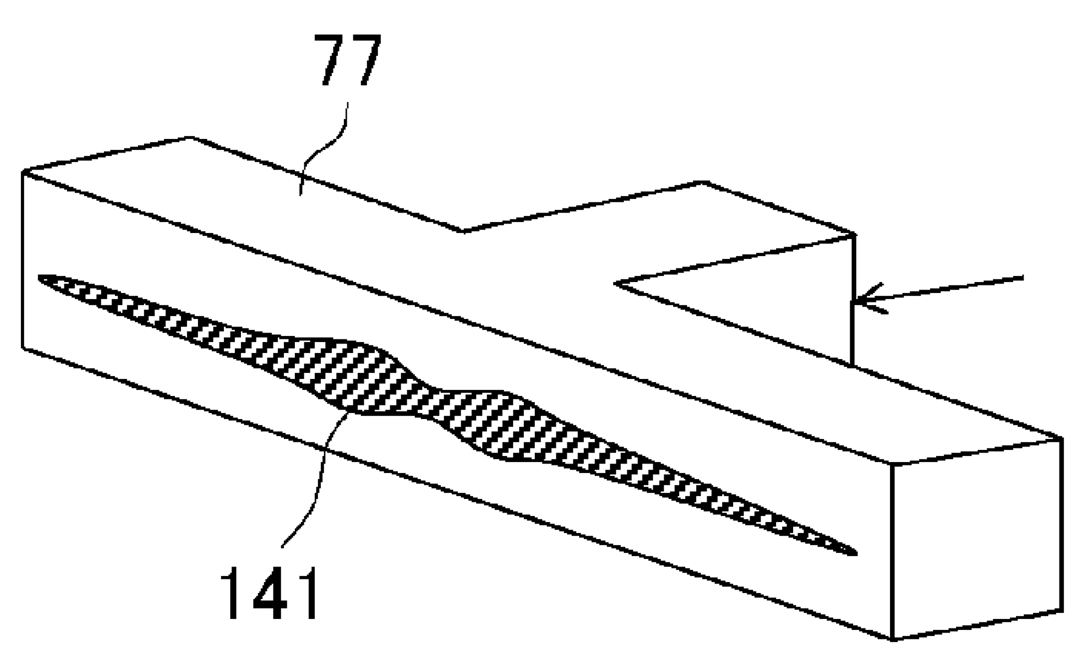


FIG. 17

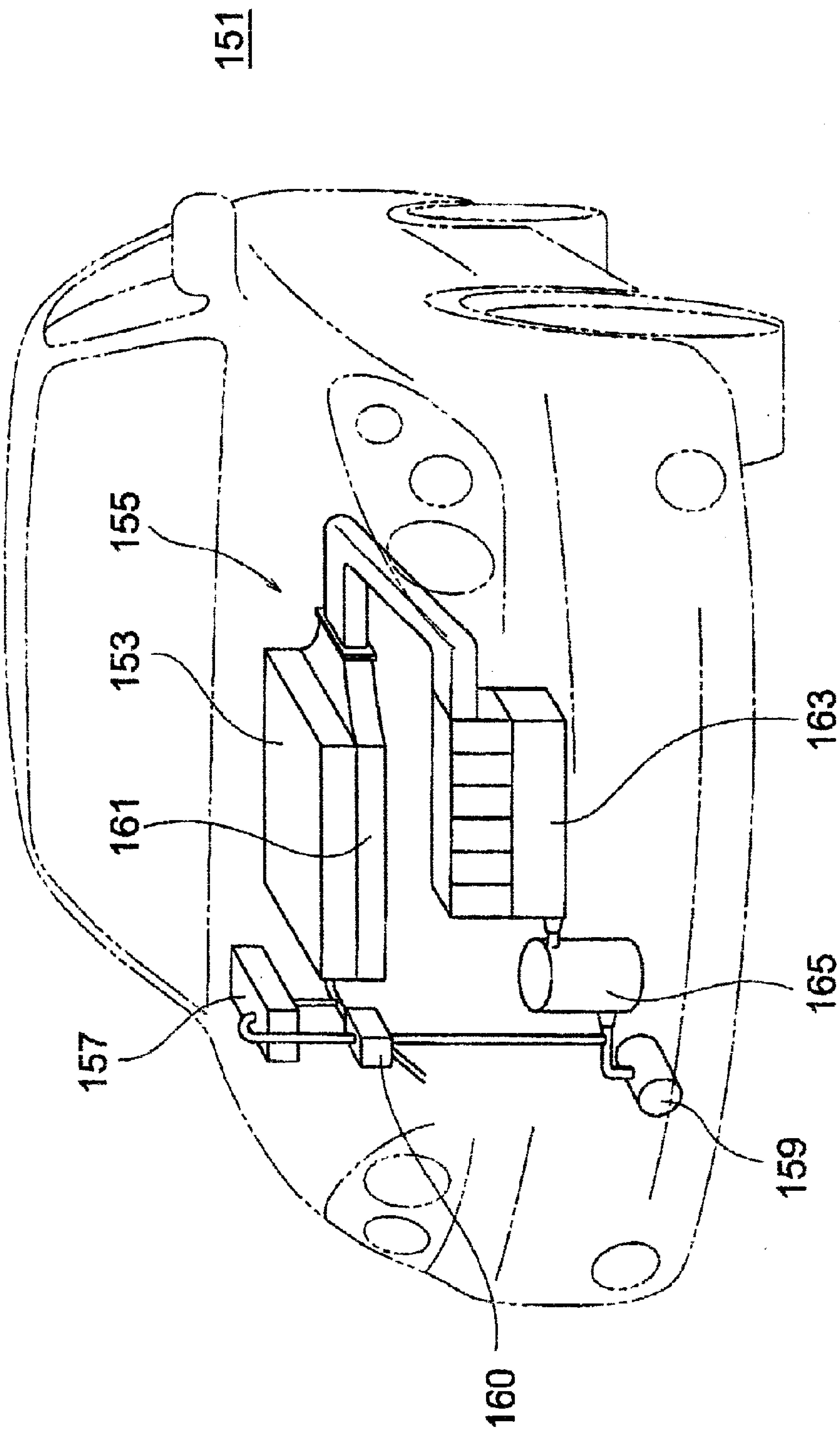


FIG. 18

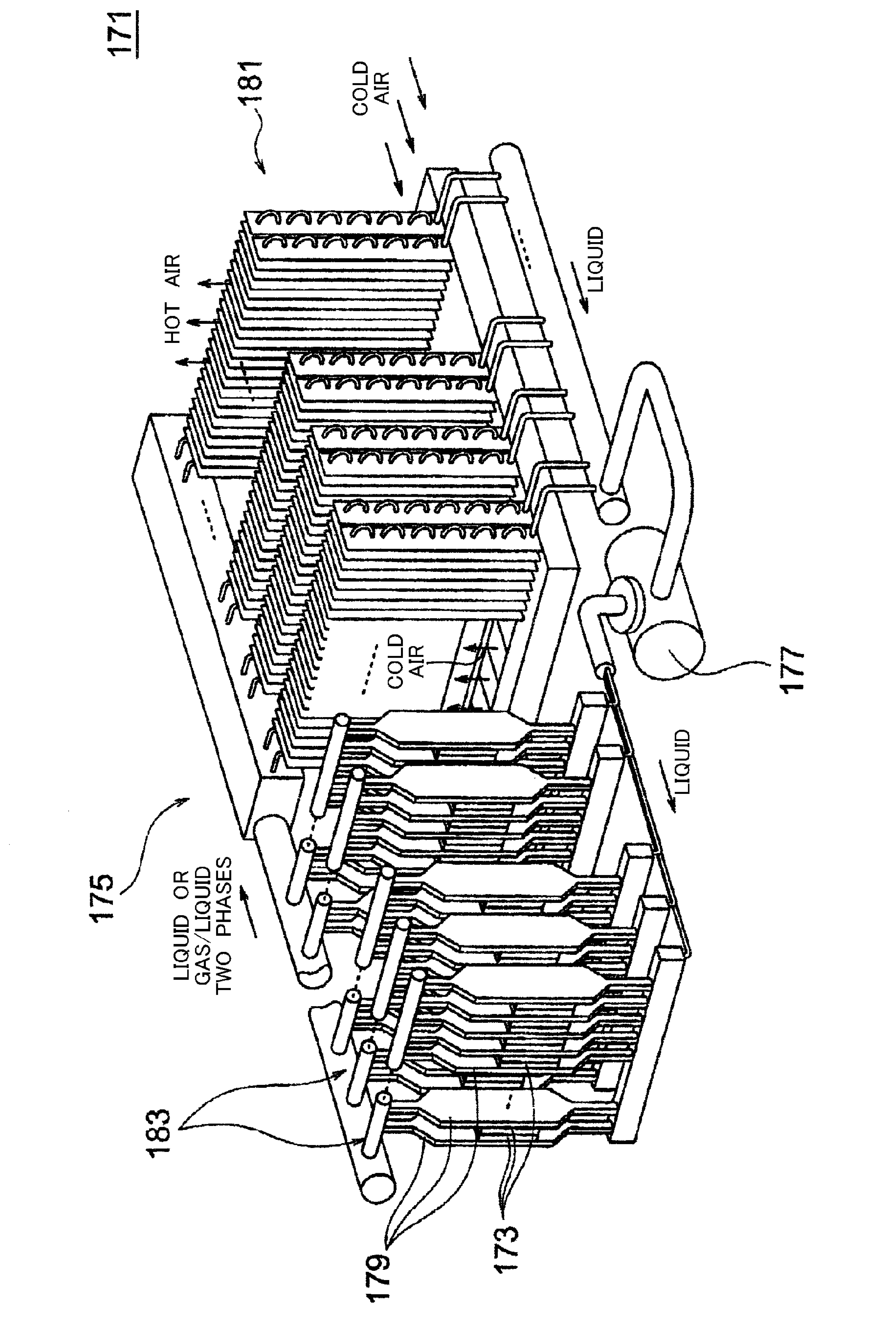

171
181
COLD AIR
HOT AIR
LIQUID
COLD AIR
177
LIQUID
175
LIQUID OR GAS/LIQUID TWO PHASES
183
179
173

FIG. 19A

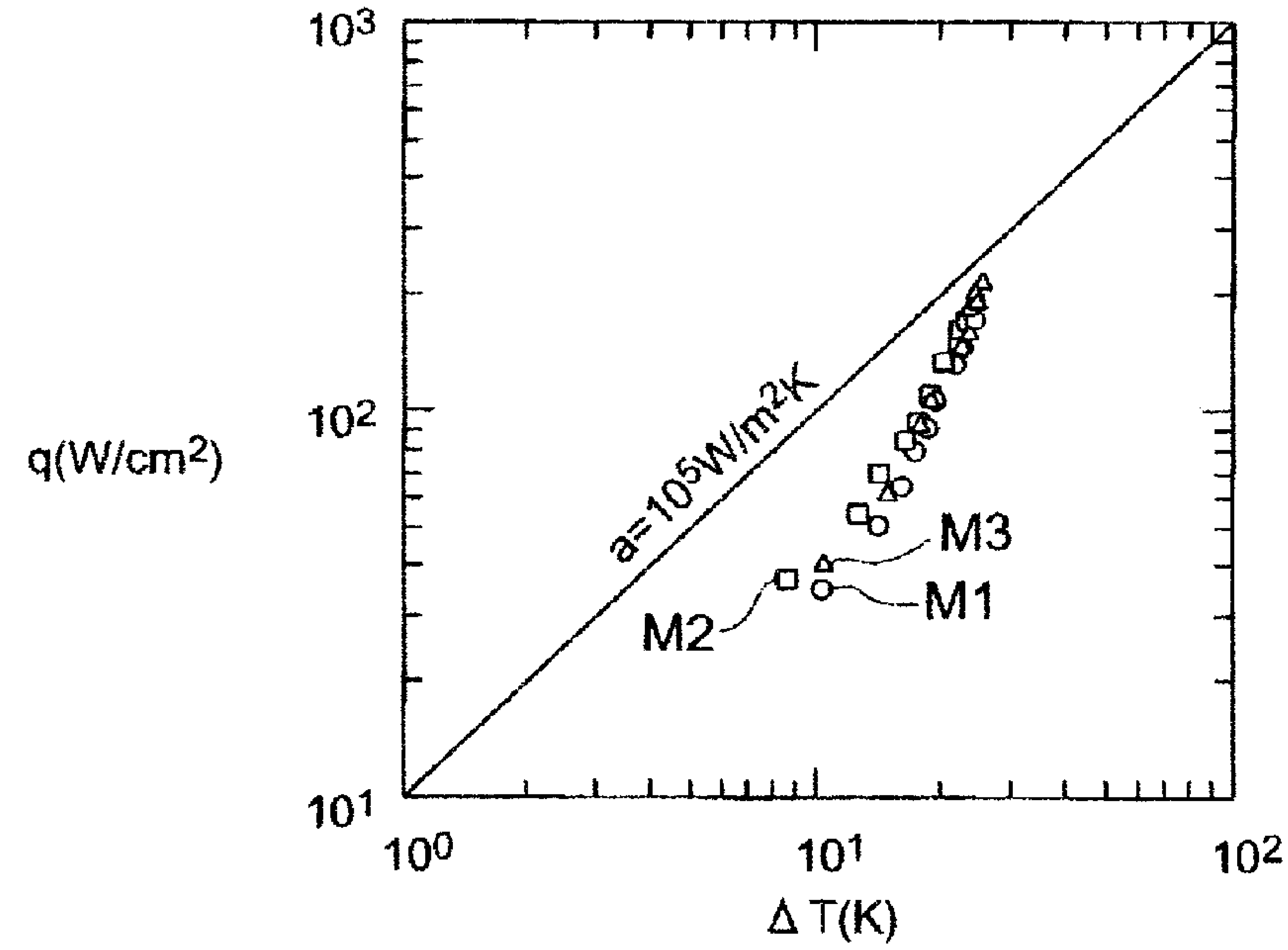
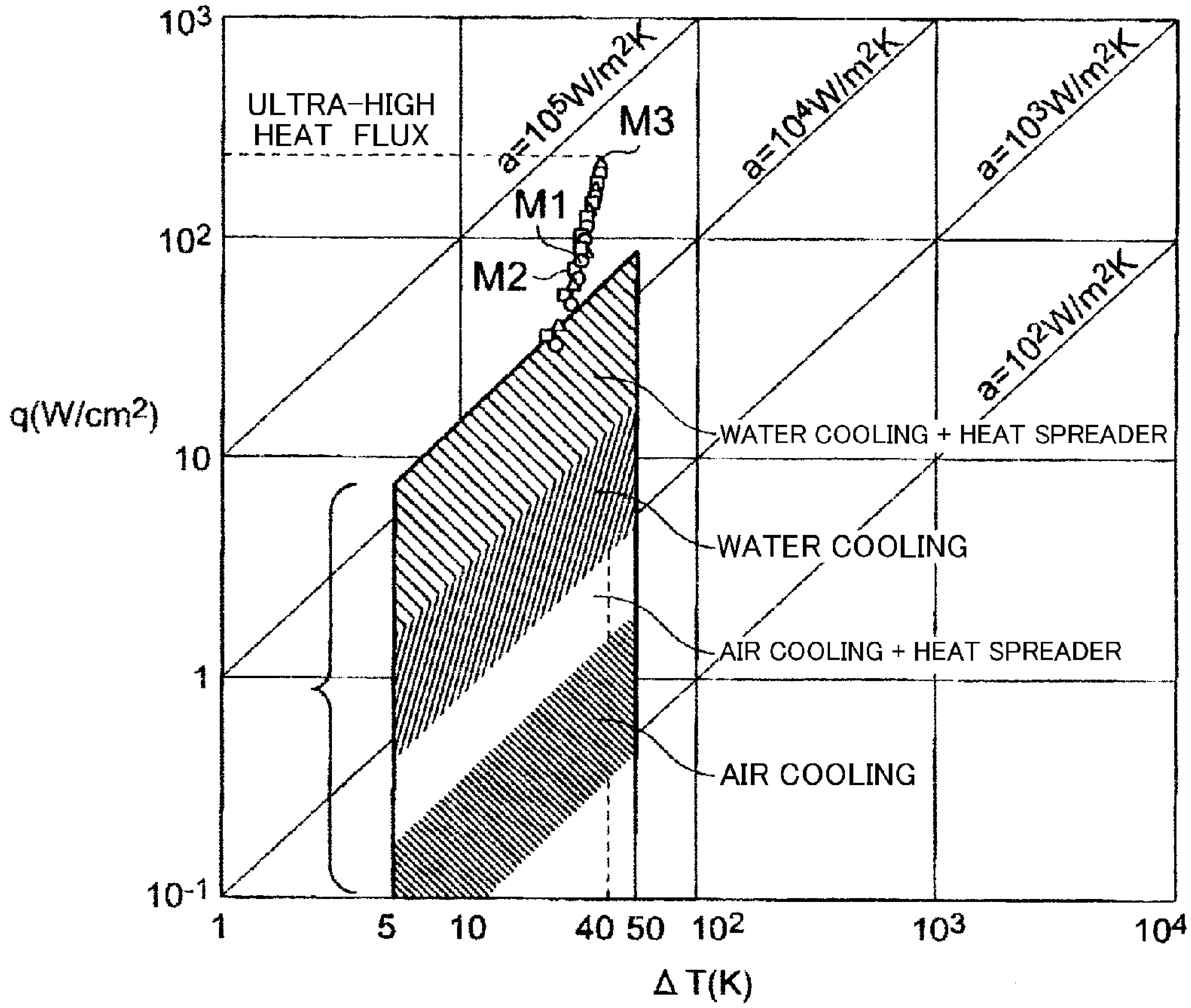


FIG. 19B



HEAT REMOVAL METHOD AND HEAT REMOVAL APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a heat removal method and a heat removal apparatus.

BACKGROUND ART

[0002] The technology of running a liquid state refrigerant in a channel adjacent to a heat removal object and cooling the heat removal object by heat-exchange between the heat removal object and the refrigerant is known. This technology is being required to handle removal of heat with a high heat flux from a further larger area due to a rapid increase of heat generation densities of electronic apparatuses and the spread of large sized semiconductors for transforming electric power.

[0003] FIG. **14** is a diagram explaining a problem occurring in a case where a channel is made longer in order to remove heat from a large area etc. for a conventional heat removal channel **501**. In FIG. **14**, a plan view is shown on the left side of the sheet surface, and cross-sectional views at the positions y**501** to y**504** in the plan view are shown on the right side of the sheet surface at the positions y**501** to y**504**.

[0004] The heat removal use channel **501** extends in a y-direction as shown in the plan view on the left side of the sheet surface of FIG. **14** and is run through by a liquid state refrigerant RL from an end portion **501***a* as shown by arrows A**501**. The heat removal object (not shown) is arranged on, for example, a negative side in a z-direction of the heat removal use channel **501** and heats a bottom surface **501***b* of the heat removal use channel **501** as indicated by arrows A**502** in the cross-sectional views on the right side of the sheet surface of FIG. **14**. In other words, the heat removal use channel **501** removes the heat of the heat removal object by the bottom surface **501***b*.

[0005] At the position of y**501**, the liquid state refrigerant RL fills the heat removal use channel **501**. At the position of y**502**, a portion of the liquid state refrigerant RL evaporates, and bubbles are generated by a gas state refrigerant RG. Note that bubbles are generated on the heated bottom surface **501***b* side in the heat removal use channel **501**. The bubbles expand and are join at the position of y**503** resulting in less of an amount of the liquid state refrigerant RL on the bottom surface **501***b* side. Further, at the position of y**504**, only the gas state refrigerant RG exists on the bottom surface **501***b* side, and the liquid state refrigerant RL exists in a liquid film state on only a top surface **501***c* facing the bottom surface **501***b*.

[0006] Namely, when making the heat removal use channel **501** longer, as shown at the position of y**504**, a so-called burnout phenomenon occurs, so the heat removal object cannot sufficiently exchange heat with the liquid state refrigerant RL, and the cooling capability remarkably falls. Accordingly, in the heat removal use channel **501** shown in FIG. **14**, it is regarded as a prerequisite that the liquid state refrigerant RL be filled from an upstream side to a downstream side of the heat removal use channel **501**.

[0007] Patent Document 1 discloses a technique of providing a sub channel extended along a main channel at a position further apart from the heat removal object than the main channel serving as the heat removal use channel and supplying the liquid state refrigerant from the sub channel to the main channel via a plurality of communicating holes communicating the main channel and the sub channel to thereby make temperature of the liquid state refrigerant uniform from the upstream side to the downstream side of the main channel. Further, in Patent Document 1, a burnout phenomenon is prevented by providing a bursting device for bursting bubbles generated in the main channel.

[0008] Patent Document 1: Japanese Patent Publication (A) No. 2005-79337

DISCLOSURE OF THE INVENTION

Problem to be Solved by the Invention

[0009] The prior art shown in FIG. **14** and the technique of Patent Document 1 are based on running a liquid state refrigerant filled in a heat removal use channel (main channel), therefore there is an apprehension that various problems may arise. For example, the refrigerant utilizing latent heat for the heat removal is limited to a very small part of the refrigerant flowing through the main channel. For this reason, the heat flux cannot help but become small. In order to remove a required heat quantity from the heat removal object, a large amount of refrigerant must be run with respect to the heat removal area, so the heat removal apparatus becomes larger in size or the required pump power increases. Further, even if these are performed, in the heat removal from a large area extended in a downstream direction, it is fully predictable that burnout as shown at the position of y**504** of FIG. **14** will be reached. For these reasons, there is an apprehension that problems may arise such as heat removal from a large area becoming difficult. Other than this, there is an apprehension that problems such as pressure loss and pulsation in the flow of the main channel may occur because of the merging of the flow of the refrigerant in the sub channel with the flow of the refrigerant in the main channel, and a member or device for bursting bubbles generated in the main channel must be provided.

[0010] Desirably a heat removal method and a heat removal apparatus capable of removing heat with a high heat flux from a large area are provided.

Means for Solving the Problems

[0011] A heat removal method of a first aspect of the present invention removes heat of a heat removal object by supplying a liquid state refrigerant into a heat removal use channel provided adjacent to the heat removal object at a plurality of positions in a predetermined direction of the heat removal use channel, forming a liquid film of the refrigerant over the plurality of positions on an inner circumferential surface of the heat removal use channel, making the liquid film evaporate by the heat from the heat removal object, and discharging the evaporated refrigerant from the heat removal use channel.

[0012] Preferably, the predetermined direction is a flow direction of the heat removal use channel.

[0013] A heat removal method of a second aspect of the present invention removes heat of a heat removal object by supplying a liquid state refrigerant into a heat removal use channel provided adjacent to the heat removal object within a predetermined range of a flow direction of the heat removal use channel, forming a liquid film of the refrigerant over the predetermined range on the inner circumferential surface of the heat removal use channel, making the liquid film evaporate by the heat from the heat removal object, and discharging the evaporated refrigerant from the heat removal use channel.

[0014] A heat removal apparatus of a third aspect of the present invention has a heat removal use channel provided adjacent to a heat removal object; and a liquid supply portion constructed to supply a liquid state refrigerant into the heat removal use channel at a plurality of positions in a predetermined direction of the heat removal use channel and form a liquid film of the refrigerant over the plurality of positions on the inner circumferential surface of the heat removal use channel.

[0015] Preferably, the predetermined direction is a flow direction of the heat removal use channel.

[0016] Preferably, the liquid supply portion has a liquid supply use channel which is adjacent to the heat removal use channel and in which the liquid state refrigerant flows, and a wall portion partitioning the heat removal use channel and the liquid supply use channel has refrigerant passage portions constructed to allow passage of the liquid state refrigerant from the liquid supply use channel to the heat removal use channel at the plurality of positions.

[0017] Preferably, the heat removal use channel is partitioned to a plurality of sections in the flow direction, and the plurality of sections each are provided with discharge ports discharging the gas state refrigerant.

[0018] Preferably, the heat removal use channel has discharge ports of the refrigerant provided at both ends in the flow direction.

[0019] Preferably, the inner circumferential surface of the heat removal use channel is provided with groove portions.

[0020] Preferably, the inner circumferential surface of the heat removal use channel is provided with groove portions extending in a direction traversing the heat removal use channel.

[0021] Preferably, the inner circumferential surface of the heat removal use channel is provided with groove portions extending in a direction along the heat removal use channel.

[0022] Preferably, the inner circumferential surface of the heat removal use channel is lined by a sheet through which the liquid state refrigerant can permeate.

[0023] Preferably, the inner circumferential surface of the heat removal use channel is roughened.

EFFECT OF THE INVENTION

[0024] According to the present invention, heat can be removed from a large area with a high heat flux.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. **1** A diagram showing an overall construction of a heat removal apparatus of an embodiment of the present invention.

[0026] FIG. **2** Diagrams schematically showing an example of the construction of a heat removal portion of the heat removal apparatus of FIG. **1**.

[0027] FIG. **3** A diagram explaining a heat removal method in an example of the structure of the heat removal portion of FIG. **2**A to FIG. **2**C.

[0028] FIG. **4** Diagrams explaining effects of the heat removal apparatus of FIG. **1** captured from another viewpoint.

[0029] FIG. **5** Diagrams explaining modifications of a liquid supply method to a heat removal use channel from a viewpoint of a heating length.

[0030] FIG. **6** Cross-sectional views showing modifications of the supply method of liquid to the heat removal use channel.

[0031] FIG. **7** Diagrams explaining patterns of flow in a liquid supply use channel and the heat removal use channel.

[0032] FIG. **8** Diagrams showing modifications wherein patterns of flow in the liquid supply use channel and the heat removal use channel are three-dimensionally extended.

[0033] FIG. **9** Perspective views showing modifications of a wall portion partitioning the heat removal use channel and the liquid supply use channel and communicating holes.

[0034] FIG. **10** Diagrams explaining examples of patterns of an inner circumferential surface of the heat removal use channel.

[0035] FIG. **11** Diagrams showing a modification wherein the heat removal use channel is magnified in a width direction of the channel.

[0036] FIG. **12** Diagrams showing a modification wherein the heat removal use channel is magnified in the flow direction.

[0037] FIG. **13** A diagram showing a modification of the overall construction of the heat removal apparatus.

[0038] FIG. **14** A diagram showing a conventional heat removal use channel.

[0039] FIG. **15** Diagrams explaining a supply rate of a liquid state refrigerant from the liquid supply use channel to the heat removal use channel.

[0040] FIG. **16** Diagrams showing examples of making a fluid resistance of the refrigerant passage portion small in an upstream portion and large in a downstream portion in the liquid supply use channel.

[0041] FIG. **17** A diagram showing an example of application of the present invention.

[0042] FIG. **18** A diagram showing another example of application of the present invention.

[0043] FIG. **19** Diagrams explaining effects of the present invention

DESCRIPTION OF NOTATIONS

[0044] **1** . . . heat removal apparatus, **12** . . . heat removal portion, **31** . . . heat removal use channel, **32** . . . liquid supply use channel, **38** . . . communicating holes, and HO . . . heat removal object.

BEST MODE FOR CARRYING OUT THE INVENTION

[0045] FIG. **1** is a diagram showing an overall construction of a heat removal apparatus **1** according to an embodiment of the present invention. The heat removal apparatus **1** has a storage tank **3** storing the liquid state refrigerant RL, a pump **5** pumping out the refrigerant in the storage tank **3** etc., a heat removal portion **12** removing the heat of the heat removal object HO (see FIG. **2**A to FIG. **2**C) by the refrigerant pumped out from the pump **5**, a condensation portion **14** condensing a gas state refrigerant flowing out of the heat removal portion **12**, a gas and liquid phase separator **19** separating the refrigerant flowing out of the condensation portion **14** to the gas state refrigerant and the liquid state refrigerant, and a subcooling portion **21** subcooling the refrigerant flowing out of the gas and liquid phase separator **19** for preventing cavitation of the pump **5**. The refrigerant subcooled by the subcooling portion **21** is pumped out by the pump **5** or stored in the storage tank **3**.

[0046] The storage tank **3** is constructed by, for example, an accumulator and is used for keeping the pressure of a circulation system of the heat removal apparatus **1** at a predetermined pressure and also fine adjustment of the liquid temperature in accordance with load fluctuations. The pump **5** is driven by a motor **6**. The operation of the motor **6** is controlled by a control unit **7**. The condensation portion **14** is, for example, an air cooled type. The air for heat exchange with the refrigerant is sent into this by a fan **15**. The fan **15** is driven by a motor **16**. The operation of the motor **16** is controlled by a control unit **17**. The subcooling portion **21** is, for example, an air cooled type. The air for heat exchange with the refrigerant is sent into this by a fan **22**. The fan **22** is driven by a motor **23**. The operation of the motor **23** is controlled by a control unit **24**.

[0047] Between the pump **5** and the heat removal portion **12**, a flow rate sensor **9** detecting the flow rate of the liquid state refrigerant RL flowing into the heat removal portion **12** and a temperature sensor **10** detecting the temperature of the liquid state refrigerant RL flowing into the heat removal portion **12** are provided. The control unit **7** controls the operation of the motor **6** based on a detection result of the flow rate sensor **9**, the control unit **17** controls the operation of the motor **16** based on the detection result of the temperature sensor **10**, and the control unit **24** controls the operation of the motor **23** based on the detection result of the temperature sensor **10**.

[0048] In the heat removal portion **12**, the heat is removed by making the refrigerant absorb the heat having a quantity Q from the heat removal object HO. At the condensation portion **14** and subcooling portion **21**, heats having quantities Q**1** and Q**2** absorbed by the refrigerant are released. Note that, assuming that there is no heat loss from piping, Q=Q**1**+Q**2** stands.

[0049] FIG. **2**A to FIG. **2**C are diagrams schematically showing the construction of the heat removal portion **12**, in which FIG. **2**A is a partially see-through perspective view, FIG. **2**B is a cross-sectional view taken along a IIb-IIb arrow direction of FIG. **2**A, and FIG. **2**C is a cross-sectional view seen from an x-direction showing enlarged an area E surrounded by a solid line in FIG. **2**A. Note that, for convenience, in some cases the z-direction is expressed as the up and down direction, but the heat removal portion **12** can exhibit a constant heat removal effect when any of the x-direction, y-direction, and z-direction becomes the up and down direction depending on its size or other various conditions.

[0050] The heat removal portion **12** has a heat removal use channel **31** provided adjacent to the heat removal object HO and a liquid supply use channel **32** for supplying the liquid state refrigerant to the heat removal use channel **31**. Note that the liquid supply use channel **32** or a refrigerant pumping system including the pump **5** etc. in addition to the liquid supply use channel **32** is an example of the liquid supply portion of the present invention.

[0051] The heat removal use channel **31** is formed by, for example, a first plate shaped member **34** provided abutting against the heat removal object HO, a second plate shaped member **35** arranged facing the first plate shaped member **34**, and two pipes **36** arranged between the first plate shaped member **34** and the second plate shaped member **35** and extending in the flow direction of the heat removal use channel **31** (flow direction of refrigerant, length direction of channel, y-direction) parallel to each other in a region surrounded by these members. Note that the heat removal object may be arranged not only on the first plate shaped member **34** side, but also on the second plate shaped member **35** side. Further, a rectangular duct or other hollow body with an appropriate cross-sectional shape may be used in place of the pipe **36**. In the heat removal use channel **31**, one end in the flow direction (positive side of the y-direction) is open and connected to the condensation portion **14**. The other end of the flow direction is closed by a not shown wall portion.

[0052] The first plate shaped member **34**, second plate shaped member **35**, and pipe **36** may be formed by a metal, plastic, or other appropriate material. The first plate shaped member **34** and second plate shaped member **35** and the pipe **36** may, for example, be joined by using a binder or solder, joined by welding or fusing, or otherwise appropriately joined.

[0053] The liquid supply use channel **32** is formed inside the pipe **36** by the pipe **36**. The position of the liquid supply use channel **32** may be a position superposed or not superposed on the heat removal object HO when seen in the z-direction. One end portion **36***b* of the pipe **36** is open whereby an inflowing port **37** is formed. The end portion **36***b* is connected to the pump **5**. Note that the other end portion **36***c* of the pipe **36** is closed. Further, in the pipe **36**, in the wall portion **36***a* partitioning the heat removal use channel **31** and the liquid supply use channel **32**, communicating holes **38** communicating the heat removal use channel **31** and the liquid supply use channel **32** are provided at a plurality of positions in the flow direction (y-direction) of the heat removal use channel **31**. the communicating hole **38** is one example of the refrigerant passage portion of the present invention. The plurality of communicating holes **38** have the same diameters relative to each other and are provided at equal intervals.

[0054] In the first plate shaped member **34**, groove portions **40** extending in a direction perpendicular to the flow direction of the heat removal use channel **31** (width direction, x-direction) are formed in a surface forming the inner circumferential surface of the heat removal use channel **31**. A plurality of groove portions **40** are provided in the flow direction of the heat removal use channel **31**. For example, the same number of groove portions **40** as the number of the plurality of communicating holes **38** are provided at the same positions of the plurality of communicating holes **38**.

[0055] FIG. **3** is a diagram explaining the heat removal method in the heat removal portion **12**. In FIG. **3**, a plan view is shown on the left side of the sheet surface, and cross-sectional views at the positions y**1** to y**3** in the plan view are shown on the right side of the sheet surface at the positions of y**1** to y**3**.

[0056] In the heat removal portion **12**, as indicated by an arrow A**1** in FIG. **2**A, the liquid state refrigerant RL pumped out by the pump **5** flows into the liquid supply use channel **32** from the inflowing port **37**. The liquid state refrigerant RL flowing into the liquid supply use channel **32** flows into the heat removal use channel **31** from the communicating holes **38** as indicated by an arrow A**2** in FIG. **2**A and an arrow A**5** in FIG. **3**.

[0057] The liquid state refrigerant RL flowing into the heat removal use channel **31** forms a liquid film on the inner circumferential surface on the first plate shaped member **34** side of the heat removal use channel **31**. The communicating holes **38** are provided at a plurality of positions in the flow direction of the heat removal use channel **31**, therefore the liquid film of the refrigerant RL is formed over the entire flow direction from the upstream side to the downstream side of the heat removal use channel **31**.

[0058] Then, as indicated by arrows A**6** in the cross-sectional views on the right side of the sheet surface of FIG. **3**, the heat from the heat removal object HO is transmitted to the first plate shaped member **34** and the liquid film of the refrigerant RL evaporates and becomes the gas state refrigerant RG. In other words, the refrigerant absorbs the heat in an amount approximately corresponding to the latent heat from the heat removal object HO.

[0059] The gas state refrigerant RG of the heat removal use channel **31** flows out of an opening end portion and flows into the condensation portion **14** as indicated by an arrow A**3** of FIG. **2**A. Note that a fan or other exhausting means for exhausting the gas state refrigerant RG may be provided in the channel as well.

[0060] For formation of a liquid film in the heat removal use channel **31**, the various parameters may be set or control performed as follows.

[0061] In the heat removal use channel **31**, the following equation (1) stands:

$$\rho_1 \times dV/dt \times (C_{pl} \times (T_s - T_{in}) + h_{fg} \times X_{out}) = Q \quad (1)$$

[0062] where,

[0063] Q: Heat removal amount per unit time (W)

[0064] ρ_1: Density of liquid state refrigerant (kg/m^3)

[0065] dV/dt: Supply rate of liquid state refrigerant to heat removal use channel per unit time (m^3/s)

C_{pl}: Specific heat at constant pressure of liquid state refrigerant (J/kgK)

[0066] T_s: Saturation temperature of refrigerant in heat removal use channel (K)

[0067] T_{in}: Temperature of liquid state refrigerant when it is supplied to heat removal use channel (K)

[0068] h_{fg}: Evaporation latent heat of refrigerant (J/kg)

X_{out}: Mass ratio of evaporation flow rate with respect to total flow rate of refrigerant of heat removal use channel

[0069] From equation (1), the following equation (2) is obtained:

$$X_{out} = ((Q/(\rho_1 \times dV/dt) - C_{pl} \times (T_s - T_{in}))/h_{fg} \quad (2)$$

[0070] Accordingly, in the heat removal apparatus **1**, if various parameters are set so that X_{out} becomes the predetermined value, a liquid film can be formed in the heat removal use channel **31**. If showing an example of the range of X_{out} in which the liquid film is preferably formed, the range is 0.2 to 1.

[0071] Q is determined according to the heat removal amount required in the heat removal object HO. ρ_1, C_{pl}, and h_{fg} can be adjusted by selection of component ingredients of the refrigerant or selection of the working pressure. dV/dt, T_{in}, and T_s can be adjusted by structural aspects of the various means at the time of design of the heat removal apparatus **1** and can be adjusted by operations of the various means at the time of the operation of the heat removal apparatus **1**.

[0072] The X_{out} at the time of the operation of the heat removal apparatus **1** is, for example, controlled as follows.

[0073] dV/dt is detected by the flow rate sensor **9**. The control unit **7** controls the operation of the pump **5** via the motor **6** based on the detection value of the flow rate sensor **9** so that dV/dt approaches a predetermined target value. Namely, dV/dt is feedback controlled by the control unit **7**, whereby X_{out} is controlled.

[0074] T_{in} is detected by the temperature sensor **10**. The control unit **17** controls the operation of the motor **16** based on the detection value of the temperature sensor **10** so that T_{in} approaches a predetermined target value. Further, the control unit **24** controls the operation of the motor **23** based on the detection value of the temperature sensor **10** so that T_{in} approaches the predetermined target value. Namely, T_{in} is feedback controlled by the control unit **17** and control unit **24**, whereby X_{out} is controlled.

[0075] Note that the control unit **17** (condensation portion **14**) and the control unit **24** (subcooling portion **21**) may appropriately play roles in the control of T_{in}. For example, at the time of start of the operation, T_{in} is feedback controlled in the condensation portion **14**, and the cooling in the subcooling portion **21** is suspended. When the temperature of the refrigerant rises up to the predetermined temperature or more, the speed of the motor **16** is made constant in the condensation portion **14** to make the cooling efficiency constant, and T is feedback controlled in the subcooling portion **21**.

[0076] T_s is determined according to the pressure in the heat removal use channel **31**. Accordingly, T_s is strongly influenced by an amount of the heat dissipation by the fans **15** and **22**. However, if the heat transmission at the condensation portion **14** or the subcooling portion **21** is changed by the adjustment of dV/dt, T_s can be indirectly controlled by controlling the expansion ratio etc. of the refrigerant. Further, for example, a pressure sensor may be provided in the heat removal use channel **31**, a pressure adjustment valve may be provided in the channel to the condensation portion **14**, and the operation of the pressure adjustment valve may be controlled based on the detection result of the pressure sensor.

[0077] According to the above embodiment, the liquid state refrigerant RL is supplied to a plurality of positions in the flow direction of the heat removal use channel **31** provided adjacent to the heat removal object HO, and a liquid film of the refrigerant RL is formed over the plurality of positions on the inner circumferential surface of the heat removal use channel **31**, therefore the refrigerant can be efficiently evaporated without depleting the liquid state refrigerant RL within a wide range from the upstream side to the downstream side of the heat removal use channel **31**. Accordingly, in comparison with the conventional case, the ratio of the heat removal amount by latent heat with respect to the heat removal amount by sensible heat greatly increases, and heat can be removed with a high heat flux from a large area. Also, the flow rate (mass) of the refrigerant can be reduced, and a reduction of size of the heat removal apparatus **1** and the heat removal use channel **31** can be achieved. The flow rate is kept low, the pressure loss is smaller than that in Patent Document 1 due to vapor running through the main channel, and the pump capability given by a product of the two is greatly reduced. The liquid state refrigerant RL removes heat by the latent heat. Therefore, in comparison with the case of heat removal by sensible heat or boiling as in the conventional case, the heat transmission is very good. The temperature of the refrigerant RL need not be very low with respect to a permissible temperature (target temperature after heat removal) of the heat removal object HO. For this reason, the cooling capability demanded from the condensation portion **14** and subcooling portion **21** can be lowered. In the condensation portion **14** and the subcooling portion **21**, the temperature difference between the refrigerant flowing in their internal portions and the open air becomes large, so it becomes possible to efficiently cool the refrigerant. Therefore the condensation portion **14** and the subcooling portion **21** can be reduced in size. The invention is based on running a gas state refrigerant through the heat removal use channel **31**, therefore the various problems which occur when running a liquid state refrigerant through the heat removal use channel do not occur. For example, the merging of the flow of the sub channel with that of the main channel and resultant unstable flow of the main channel as in Patent Document 1 will not occur. It is not necessary to provide a member or device for bursting the les generated in the main channel either.

[0078] The heat removal apparatus **1** has the liquid supply use channel **32** extending along the heat removal use channel **31** and allowing the liquid state refrigerant RL to pass therethrough. Communicating holes **38** communicating the heat removal use channel **31** and the liquid supply use channel **32** are provided at a plurality of positions in the flow direction of the heat removal use channel **31** in the wall portion **36*a*** partitioning the heat removal use channel **31** and the liquid supply use channel **32**. Therefore, while the construction is simple, the liquid film can be formed by supplying the refrigerant to a plurality of positions in the flow direction of the heat removal use channel **31**.

[0079] At the inner circumferential surface of the heat removal use channel **31**, the groove portions **40** extending in the direction perpendicular to the heat removal use channel **31** are provided, therefore the liquid film easily spreads in the direction perpendicular to the heat removal use channel **31**, and the depletion of the refrigerant at a position away from the liquid supply use channel **32**, that is, the center side position of the heat removal use channel **31**, is suppressed. Note that the principle of the spread of the liquid state refrigerant by the groove portions **40** is as follows. The liquid state refrigerant RL sticks to the side surfaces (inclined surfaces) of each groove portion **40** due to surface tension, so the surface of the liquid state refrigerant RL in each groove portion **40** is concave. Although the contact angles formed by the surface of the refrigerant RL and the side surfaces of the groove portion **40** is equivalent between the center side of the heat removal use channel **31** and the side portion side (liquid supply use channel **32** side), the refrigerant becomes depleted the more toward the center side and the amount of the refrigerant RL is smaller. Therefore, the curvature of the concave surface becomes larger toward the center side. For this reason, the force causing the refrigerant RL to shrink becomes stronger toward the center side, and a state of balance with a high gas pressure is exhibited. However, the magnitude of the gas state refrigerant RG covering the surface of the refrigerant RL is equivalent between the center side and the side portion side. For this reason, the refrigerant RG of the liquid automatically flows to the center side since a negative pressure gradient is caused from the side portion side to the center side.

[0080] FIG. **4**A to **4**C are diagrams explaining the effects of the heat removal apparatus **1** of the present embodiment grasped from another viewpoint.

[0081] FIG. **4**A shows a situation of the refrigerant in the conventional heat removal use channel **501**. In the conventional heat removal use channel **501**, the liquid state refrigerant RL flows into the heat removal use channel **501** from one end (arrow **7**A) and flows toward the other end. Accordingly, a length L**501** of the flow direction of the heat removal use channel **501** becomes a heating length of heating of the refrigerant. When the length L**501** exceeds a constant length, the liquid state refrigerant RL evaporates to become the gas state refrigerant RG and is discharged from the downstream side of the heat removal use channel **501** (arrow A**8**). Namely, on the downstream side of the heat removal use channel **501**, a dry out phenomenon occurs and the inner circumferential surface is depleted of the refrigerant RL, so the cooling capability is remarkably lowered.

[0082] However, as shown in FIG. **4**B, in the heat removal use channel **31** of the present embodiment, the liquid state refrigerant RL is supplied from both sides of the heat removal use channel **31** to the direction perpendicular to the flow direction, therefore the heating length becomes a length L**1** of half of the width of the heat removal use channel **31**. Accordingly, if the liquid state refrigerant RL is supplied in an amount by which the refrigerant RL is not depleted for the period where it flows through the length L**1**, the cooling capability can be exhibited over the entire surface of the heat removal use channel **31**. In other words, the influence of the length of the heat removal use channel **31** in the flow direction exerted upon the depletion of the refrigerant RL is remarkably reduced, and the degree of freedom in setting the length of the flow direction is improved.

[0083] Note that, as shown in FIG. **4**C, in the heat removal use channel **31** of the present embodiment as well, if the width of the heat removal use channel **31** becomes large and a heating length (L**2**) becomes long with respect to the amount of supply of the liquid state refrigerant RL, the liquid state refrigerant RL is depleted at the center side of the heat removal use channel **31**. Accordingly, it is necessary to appropriately set the width of the heat removal use channel **31** and the amount of supply of the liquid state refrigerant RL.

[0084] FIG. **5**A to FIG. **5**D are diagrams explaining modifications of the method of supply of the liquid to the heat removal use channel from the viewpoint of the heating length explained with reference to FIG. **4**A to FIG. **4**C. Note that, in FIG. **5**A to FIG. **5**D, as indicated by the arrows A**9** in FIG. **5**A, a case where the heat removal use channel is heated from both surfaces in the up and down direction of the sheet surface (corresponding to the first plate shaped member **34** side and second plate shaped member **35** side of the heat removal use channel **31**) is exemplified.

[0085] FIG. **5**A shows a modification of the supply of the liquid refrigerant from both sides of a rectangle as indicated by arrows A**10** in a heat removal use channel **41** having a rectangular cross-section. In this modification, the heating length becomes a length L**4** of the half of the width of the heat removal use channel **41**.

[0086] FIG. **5**B shows a modification of the supply of the liquid refrigerant from two facing points of a circle as indicated by the forked arrows A**11** in a heat removal use channel **42** having a circular cross-section. In this modification, the heating length becomes a length L**5** of ¼ of the circumference of the heat removal use channel **42**.

[0087] FIG. **5**C shows a modification of the supply of the liquid refrigerant from one point of a circle as indicated by a forked arrow A**12** in a heat removal use channel **43** having a circular cross-section. In this modification, the heating length becomes a length L**6** of ½ of the circumference of the heat removal use channel **43**.

[0088] FIG. **5**D shows a modification of the supply of the liquid refrigerant from four points equally arranged around the circumference as indicated by the forked arrows A**13** in a heat removal use channel **44** having a circular cross-section. In this modification, the heating length becomes a length L**7** of ⅛ of the circumference of the heat removal use channel **44**.

[0089] As shown in FIG. **5**A to FIG. **5**D, if supply ports of the liquid are increased, the heating length becomes shorter. This is advantageous for preventing the depletion of the refrigerant. However, if the supply ports increase, there is an apprehension that the number of parts and number of manufacturing steps may increase. Accordingly, the cross-sectional shape of the heat removal use channel and the positions and number of supply ports of the liquid state refrigerant are preferably set considering various conditions such as a saturation temperature of the refrigerant, size of the heat removal object, and amount of heat generated by the heat removal object. Note that FIG. **5**A to FIG. **5**D are examples of combinations of the cross-sectional shapes of the heat removal use channel and the position and number of the supply ports. Various modifications are possible other than these.

[0090] FIG. **6**A to FIG. **6**D are cross-sectional views showing modifications of the method of supply of the liquid to the heat removal use channel. Note that, in FIG. **6**A to FIG. **6**D, the heat removal object is provided on at least one side between the positive side and the negative side of the z-direction of the channel, and the flow direction of the heat removal use channel is the y-direction.

[0091] FIG. **6**A shows a modification wherein a wall portion **47** is provided in a channel having a rectangular cross-section to divide the channel into a heat removal use channel **45** and a liquid supply use channel **46**. The wall portion **47** is provided with not shown communicating holes at a plurality of positions in the flow direction (y-direction) of the heat removal use channel **45**. The liquid state refrigerant is supplied to the heat removal use channel **45** from the liquid supply use channel **46** via the communicating holes as indicated by the arrows A**15**. Note that, in this modification, by providing the wall portion **47**, the heat removal use channel **45** and the liquid supply use channel **46** can be easily constructed.

[0092] FIG. **6**B shows a modification wherein nozzles **50** are provided on both sides of the heat removal use channel **49**. The nozzles **50** are provided at a plurality of positions in the flow direction (y-direction) of the heat removal use channel **49**. The liquid state refrigerant is supplied to the heat removal use channel **49** by the nozzles **50** as indicated by the arrows A**17**. In this modification, the supply direction of the liquid can be adjusted by the adjustment of the orientations of the nozzles **50**, while the supply position of the liquid can be adjusted by adjusting the position of the front ends **50***a* of the nozzles **50** in the direction perpendicular to the flow direction of the heat removal use channel **49** (x-direction). The orientations, positions, and flow rates of the plurality of nozzles **50** may be set different from each other as well. Accordingly, change of settings in accordance with a usage environment etc. of the heat removal apparatus is easy.

[0093] FIG. **6**C shows a modification wherein pipes **51** are provided at both ends of the internal portion of a rectangular channel, a heat removal use channel **52** is formed outside the pipes **51**, and liquid supply use channels **53** are formed inside the pipes **51**. In this modification, in the same way as the embodiment shown in FIG. **2**A, the liquid refrigerant is supplied from a plurality of communicating holes formed in the pipes **51** to the heat removal use channel **52** (arrows A**19**). In this modification, by just inserting the pipes **51** into the rectangular channel, the heat removal use channel **52** and the liquid supply use channels **53** can be constructed. Further, the pipes **51** contribute to reinforcement of the structural strength of the rectangular channel.

[0094] FIG. **6**D shows a modification wherein a wall portion **55** made of a porous member is provided in the rectangular channel to form a heat removal use channel **56** and liquid supply use channels **57**. The porous member will be explained later.

[0095] FIG. **6**E shows a modification wherein a liquid supply use channel **60** having a width equivalent to that of the heat removal use channel **59** is made to run parallel to the heat removal use channel **59** while being superposed on it. Note that, in the modification of FIG. **6**E, the heat removal object is arranged on a lower side of the sheet surface of the heat removal use channel **59**. In the heat removal use channel **59** and the liquid supply use channel **60**, not shown communicating holes communicating the two are formed at both sides of the channels. A plurality of communicating holes are provided in the flow direction (y-direction) of the heat removal use channel **59**. The liquid state refrigerant of the liquid supply use channel **60** is supplied via the communicating holes to the heat removal use channel **59** as indicated by the arrow A**21**s. In this modification, the heat removal use channel **59** and the liquid supply use channel **60** are stacked up, so reduction of the width, ensuring the flow rate of the liquid supply use channel **60**, and reduction of the temperature difference between the heat removal use channel **59** and the liquid supply use channel **60** are achieved.

[0096] FIG. **6**F shows a modification wherein a nozzle **62** protruding into the heat removal use channel **49** is provided at the center of the heat removal use channel **49** in addition to the modification of FIG. **6**B. In this modification, the heat removal object is provided on a lower side of the sheet surface of the heat removal use channel **49**, and the nozzle **62** protrudes into the heat removal use channel **49** from an upper side of the sheet surface of the heat removal use channel **49**. There is a possibility of depletion of the liquid state refrigerant from the nozzle **50** before arriving at the center of the width direction. Therefore, in this modification, the liquid state refrigerant is supplied to the center of the heat removal use channel **49** by the nozzle **62** to prevent the depletion at the center in the width direction of the heat removal use channel **49**. Further, the liquid state refrigerant is supplied to the center by the nozzle **62**. Therefore, by making the front end position of the nozzle **62** approach the surface on the side heated by the heat removal object (surface on the lower side of the sheet surface), the liquid film can be reliably formed on the surface.

[0097] FIG. **6**G shows a modification wherein nozzles **65** protruding into the heat removal use channel **59** from the liquid supply use channel **60** are provided at a plurality of positions in the width direction of the heat removal use channel **59** in place of communicating holes on the two sides in the modification shown in FIG. **6**E. The liquid state refrigerant of the liquid supply use channel **60** is supplied via the nozzles **65** to the heat removal use channel **59**. In this modification, the heating length becomes the distance between nozzles **65**. Accordingly, the depletion of the liquid state refrigerant can be prevented by making the heating length further shorter than the width of the heat removal use channel **59**. In other words, extension of the heat removal use channel **59** to the width direction is possible. Further, by making the front end positions of the nozzles **65** approach the surface on the side heated by the heat removal object (surface on the lower side of the sheet surface), the liquid film can be reliably formed on the surface.

[0098] FIG. **7**A to FIG. **7**D are diagrams explaining patterns of flows in the liquid supply use channel and the heat removal use channel. In FIG. **7**A to FIG. **7**D, solid arrows indicate the flow directions of the liquid state refrigerant, and the broken line arrows indicate the flow directions of the gas state refrigerant.

[0099] In the liquid supply use channel, as in a liquid supply use channel **74** of FIG. **7**A, the liquid state refrigerant may flow in from one end **74***a* of a heat removal use channel **73** in the flow direction (y-direction) and the liquid state refrigerant may flow out of the other end **74***b*. Alternatively, as in the liquid supply use channel **68** of FIG. **7**B and the liquid supply use channel **71** of FIG. **7**C, the other ends **68***b* and **71***b* may be closed and only communicating holes (not shown) with the heat removal use channels **67** and **70** may be provided as outflow ports of the liquid state refrigerant. Further, as shown in FIG. **7**D, an inflowing port **77***a* may be provided at an appropriate position in the middle of the flow direction of a heat removal use channel **76**. The liquid state refrigerant may flow toward one end **77***b* and the other end **77***c* of this flow direction as well. In this case, as shown in FIG. **7**D, the one end **77***b* and the other end **77***c* of the liquid supply use channel **77** may be closed and only communicating holes with the heat removal use channel **76** may be provided as outflow ports of the refrigerant, or the refrigerant may flow out from one of the one end **77***b* and the other end **77***c*. Further, when both ends of the liquid supply use channel are opened as in FIG. **7**A, both may be used as inflowing ports.

[0100] In the heat removal use channel, the liquid state refrigerant may be supplied from one end **73***a* as in the heat removal use channel **73** of FIG. **7**A or the liquid state refrigerant may be supplied from only the liquid supply use channel as in the heat removal use channels of FIG. **7**B to FIG. **7**D. Further, in the heat removal use channel, the gas state refrigerant may flow out from only one end side of the flow direction as in the heat removal use channel **67** of FIG. **7**B, or the gas state refrigerant may flow out to both sides of the flow direction as in the heat removal use channel **70** of FIG. **7**C and the heat removal use channel **76** of FIG. **7**D.

[0101] As shown in FIG. **7**C and FIG. **7**D, the refrigerant can be discharged from both end sides of the heat removal use channel in the flow direction, because the heat is removed by evaporation of the liquid film formed in the heat removal use channel and the gas state refrigerant is discharged from the heat removal use channel. Namely, as in the conventional one, in the technique basically removing the heat by the sensible heat of the liquid state refrigerant or usual boiling, it is necessary to run a large amount of liquid state refrigerant through the heat removal use channel. As a result, as shown in FIG. **14**, a structure of running the liquid state refrigerant from one end to the other end of the heat removal use channel is employed. If assuming that the channel of the refrigerant is set as in FIG. **7**C in the prior art, a flow with a sufficient flow rate cannot be formed in the heat removal use channel, and a sufficient heat removal effect cannot be obtained. In the present embodiment, however, it is enough to supply a sufficient amount of refrigerant for the formation of the liquid film, therefore it is not necessary to use one end of the heat removal use channel as the inflowing port of the liquid state refrigerant, so both ends of the heat removal use channel can be utilized as outflow ports of the refrigerant. Note that by using both ends as the outflow ports, the refrigerant is quickly exhausted from the heat removal use channel and an excessive increase of the exhaust speed can be suppressed.

[0102] Further, as shown in FIG. **7**D, it is possible to provide an inflowing port of the liquid supply use channel at an optional position and direct the liquid state refrigerant toward both sides in the flow direction (y-direction), because the apparatus is constructed to remove the heat by the evaporation of the liquid film formed in the heat removal use channel and discharge the gas state refrigerant from the heat removal use channel. Namely, the conventional construction separated the flow of the liquid state refrigerant to flows of the main channel and the sub channel, then made them merge, so the flow of the main channel and the flow of the sub channel had to become the same direction. In the present embodiment, however, the gas state refrigerant flows in the heat removal use channel, and the liquid state refrigerant flows in the liquid supply use channel, therefore the flow directions can be freely set with respect to each other.

[0103] Accordingly, in the present embodiment, various flow patterns as shown in FIG. **7**A to FIG. **7**D are possible, and the degree of freedom of design is improved. Note that FIG. **7**A to FIG. **7**D are examples. The liquid state refrigerant and gas state refrigerant may be run in various patterns other than those as well.

[0104] The improvement of the degree of freedom of design of the heat removal use channel and liquid supply use channel as explained in FIG. **7**A to FIG. **7**D makes three-dimension extension of the patterns of flow in the liquid supply use channel and heat removal use channel possible as well. FIG. **8**A to FIG. **8**F are diagrams showing modifications of three-dimensionally extending patterns of flow in the liquid supply use channel and heat removal use channel. In FIG. **8**A to FIG. **8**F, the solid arrows indicate flow directions of the liquid state refrigerant, and the broken line arrows indicate flow directions of the gas state refrigerant.

[0105] FIG. **8**A is a plan view showing a modification wherein the liquid state refrigerant is supplied in a direction (z-direction) perpendicular to the heat removal object in addition to the modification shown in FIG. **7**D, while FIG. **8**B is a cross-sectional view seen from the lower portion of the sheet surface of FIG. **8**A. In this modification, the heat removal object is provided on the lower side of the sheet surface of FIG. **8**B. At the position of the center in the width direction of the heat removal use channel **76**, a liquid supply use channel **79** extended along the flow direction of a heat removal use channel **76** is provided. The liquid supply use channel **79** has, for example, the same shape as that of the liquid supply use channel **77**, but is slightly smaller. An inflowing port **79***a* through which the liquid state refrigerant is supplied is provided on the upper side of the sheet surface, and a plurality of communicating holes (not shown) for supplying the liquid state refrigerant to the heat removal use channel **76** are provided along the heat removal use channel **76** on the lower side of the sheet surface. The modification is effective for preventing depletion of liquid at the center of the heat removal use channel **76** in the same way as the modification shown in FIG. **6**F.

[0106] FIG. **8**C is a modification wherein a plurality of liquid supply use channels **79** shown in FIG. **8**A are arranged in the width direction of a heat removal use channel **81**, while FIG. **8**D is a cross-sectional view seen from the lower side of the sheet surface of FIG. **8**C. In this modification, in the same way as the modification shown in FIG. **6**G, extension to the width direction of the heat removal use channel **81** is made possible. Note that, as apparent from FIG. **8**C, in the heat removal use channel of the present invention, the flow direction does not have to be the longitudinal direction.

[0107] FIG. **8**E is a modification wherein discharge ports **83***a* for discharging the gas state refrigerant are provided in the direction perpendicular to the longitudinal direction and the width direction of the heat removal use channel **83**, while FIG. **8**F is a cross-sectional view seen from the lower side of the sheet surface of FIG. **8**E. In this modification, the heat removal object is provided on the lower side of the sheet surface of FIG. **8**F, and the discharge ports **83***a* are formed on the opposite side to the heat removal object in the inner circumferential surface of the heat removal use channel **83**. Note that, in the heat removal use channel **83**, both ends in the longitudinal direction (flow direction of the liquid supply use channel **84**) are closed, and the outflow port of the gas state refrigerant is only the discharge port **83***a*. A plurality of discharge ports **83***a* are provided along, for example, the flow direction of the liquid supply use channel **84**. In this modification, the evaporated refrigerant can be quickly discharged while being not run to the other region of the surface along the heat removal object. Note that, in FIG. **8**E, it is possible to say that the end face of the channel is arranged along the heat removal object. In other words, the heat removal use channel of the present invention does not have to be a channel through which the gas state refrigerant flows in the direction (y-direction) along the heat removal object. The gas state refrigerant discharged from the discharge ports **83***a* flows into, for example, a pipe or rectangular duct and flows to the condensation portion and subcooling portion.

[0108] FIG. **9**A to FIG. **9**E are perspective views showing modifications of the wall portion partitioning the heat removal use channel and the liquid supply use channel (see wall portion **47** of FIG. **6**A, wall portion **55** of FIG. **6**D, etc.) and communicating holes.

[0109] In the modification of FIG. **9**A, a plurality of communicating holes **86** are formed in a flat plate shaped wall portion **85**. For example, holes are formed by punching a metal plate or plastic plate. In this modification, the wall portion having communicating holes can be easily formed, and change of design of positions (for example, intervals of the plurality of communicating holes), sizes, and shapes of the communicating holes is easy.

[0110] In the modification of FIG. **9**B, a wall portion **88** is formed by a porous member. The porous member is, for example, a sintered metal. A filtration size of the porous member can be appropriately set according to, for example, the amount of supply to the heat removal use channel. It is, for example, 1 μm to 200 μm. Note that, in the conventional technique of running a liquid state refrigerant through the heat removal use channel, even when the main channel and the sub channel are partitioned by a porous member, a sufficient amount of the liquid state refrigerant cannot be supplied from the sub channel to the main channel. Note that a pore portion of the porous member is an example of the refrigerant passage portion of the present invention.

[0111] In the modification of FIG. **9**C, one slit **90** is provided extending along the longitudinal direction of a wall portion **89**. In this modification, by supplying the liquid state refrigerant into the heat removal use channel within a predetermined range of the flow direction of the heat removal use channel by the slit **90** and forming a liquid film over a predetermined range, the same effects as those by the case of supplying the liquid state refrigerant to a plurality of positions are obtained.

[0112] As shown in FIG. **9**A, where communicating holes are formed by punching etc., the sizes, shapes, and arrangement positions of the communicating holes can be appropriately changed. For example, the sizes, shapes, and positions of the communicating holes may be made uneven, unequal, and so on. The positions and numbers of communicating holes and grooves formed in the inner circumferential surface of the heat removal use channel in the direction perpendicular to the channel do not have to be the same. In the modification shown in FIG. **9**D, in a liquid supply use channel **91**, a plurality of communicating holes **92** are provided from one end **91***a*, through which the liquid state refrigerant is poured, to the other end **91***b*. These communicating holes **92** are formed so that their diameters become larger toward the other end **91***b* side. There are cases that the liquid state refrigerant can be supplied to the heat removal use channel with a uniform flow rate over the entire length from the upstream side to the downstream side of the liquid supply use channel **91** by this.

[0113] Further, in the modification shown in FIG. **9**E, communicating holes **95** are formed so that the pitch of the communicating holes **95** becomes smaller toward the end portion **94***a* and end portion **94***b* sides of the liquid supply use channel **94**. There are cases that the liquid state refrigerant can be supplied to the heat removal use channel with a uniform flow rate over the entire length from the upstream side to the downstream side of the liquid supply use channel **94** by this.

[0114] FIG. **15**A and FIG. **15**B are diagrams explaining the amount of supply of the liquid state refrigerant from the liquid supply use channel to the heat removal use channel.

[0115] The upper side diagram of FIG. **15**A is a plan view showing in a general manner the heat removal use channels **31**, **73**, and **67** shown in FIG. **2**A to FIG. **2**C, FIG. **7**A, and FIG. **7**B. The lower side diagram of FIG. **15**A is a diagram showing a pressure P**1** of the liquid supply use channel and a pressure P**2** of the heat removal use channel at positions in the flow direction in the upper side diagram of FIG. **15**A. The upper side diagram of FIG. **15**B is a plan view showing in a general manner the heat removal use channel **76** shown in FIG. **7**D. The lower side diagram of FIG. **15**B is a diagram showing the pressure P**1** of the liquid supply use channel and the pressure P**2** of the heat removal use channel at positions in the flow direction in the upper side diagram of FIG. **15**B.

[0116] In the supply of the liquid state refrigerant from the liquid supply use channel (**32**, **77**, etc.) to the heat removal use channel (**31**, **76**, etc.), if it is assumed that a flow resistance of the channel communicating the two (refrigerant passage portion; for example, communicating holes (**86**, FIG. **9**A), a pore portion of a wall portion constructed by a sintered metal or other porous member (**88**, FIG. **9**B), a slit (**90**, FIG. **9**C), or nozzles (**65**, FIG. **6**G)) is uniform along the heat removal use channel, the amount of supply of the liquid flowing in the refrigerant passage portion is determined according to a pressure difference ΔP between the two channels of the liquid supply use channel and the heat removal use channel. Namely, for the inflow of the liquid from the liquid supply use channel to the heat removal use channel, it is indispensable that the pressure of the liquid supply use channel be higher than the pressure of the heat removal use channel. Further, the distribution of flow rates from the liquid supply use channel to the heat removal use channel is determined according to the distribution of pressures of the liquid supply use channel and the heat removal use channel.

[0117] A pressure gradient in the liquid supply use channel (**32**, **77**, etc.) is gradually lowered since the flow rate in the liquid supply use channel decreases due to the inflow of the liquid to the heat removal use channel (**31**, **76**, etc.) On the other hand, in the heat removal use channel, the flow rate keeps on increasing. In addition, the single liquid phase changes to the gas and liquid two phases due to the heating. Therefore, the pressure gradient conversely increases.

[0118] Accordingly, the pressure difference ΔP between the liquid supply use channel (**32**, **77**, etc.) and the heat removal use channel (**31**, **76**, etc.) is small in the upstream portion of the heat removal use channel, but becomes large in the downstream portion where parallel channels are assumed, therefore the amount of supply from the liquid supply use channel to the heat removal use channel in the upstream portion becomes small, and dry out sometimes easily occurs in the upstream portion.

[0119] In order to solve this, it may be considered to change the dimensions, pitch, etc. of the opening portion to make the flow resistance of the channel (refrigerant passage portion) communicating the liquid supply use channel (**32**, **77**, etc.) and the heat removal use channel (**31**, **76** etc.) small in the upstream portion of the heat removal use channel and large in the downstream portion, and make the amount of liquid supply to the heat removal use channel uniform.

[0120] FIG. **16**A to FIG. **16**F show examples in which the flow resistance of the refrigerant passage portion located at a boundary of the liquid supply use channel and the heat removal use channel is made smaller in the upstream portion of the heat removal use channel and larger in the downstream portion as described above.

[0121] FIG. **16**A shows a case where the liquid supply use channel and the heat removal use channel of FIG. **15**A are communicated by communicating holes **131**. The communicating holes **131** are set so that the diameter becomes larger toward the upstream side (right side of the sheet surface) of the liquid supply use channel and the heat removal use channel, so the flow resistance becomes smaller toward the upstream side.

[0122] FIG. **16**B shows a case where the liquid supply use channel and the heat removal use channel of FIG. **15**A are communicated by communicating holes **133**. The communicating holes **133** are set so that the pitch becomes smaller toward the upstream side (right side of the sheet surface) of the liquid supply use channel and the heat removal use channel, so the flow resistance becomes smaller toward the upstream side.

[0123] FIG. **16**C shows a case where the liquid supply use channel and the heat removal use channel of FIG. **15**A are communicated by a slit **135**. The slit **135** is set so that the width becomes larger toward the upstream side (right side of the sheet surface) of the liquid supply use channel and the heat removal use channel, so the flow resistance becomes smaller toward the upstream side.

[0124] FIG. **16**D shows a case where the liquid supply use channel and the heat removal use channel of FIG. **15**B are communicated by communicating holes **137**. The communicating holes **137** are set so that the diameter becomes larger toward the upstream side (center side of the liquid supply use channel **77**) of the liquid supply use channel and the heat removal use channel, so the flow resistance becomes smaller toward the upstream side.

[0125] FIG. **16**E shows a case where the liquid supply use channel and the heat removal use channel of FIG. **15**B are communicated by communicating holes **139**. The communicating holes **139** are set so that the pitch becomes smaller toward the upstream side (center side of the liquid supply use channel **77**) of the liquid supply use channel and the heat removal use channel, so the flow resistance becomes smaller toward the upstream side.

[0126] FIG. **16**F shows a case where the liquid supply use channel and the heat removal use channel of FIG. **15**B are communicated by a slit **141**. The slit **141** is set so that the width becomes larger toward the upstream side (center side of the liquid supply use channel **77**) of the liquid supply use channel and the heat removal use channel, so the flow resistance becomes smaller toward the upstream side. However, the flow resistance is made relatively larger a little in the center portion where the pressure of the liquid supply use channel locally becomes high due to collision of the inflowing liquid.

[0127] Note that, there also exists a case where dry out is caused in the downstream portion where the amount of passage of the generated vapor is large. In this case, the method of increasing the flow rate in the downstream portion as shown in FIG. **9**D and FIG. **9**E becomes effective.

[0128] FIG. **10**A to FIG. **10**F are diagrams explaining patterns of the inner circumferential surface of the heat removal use channel. In FIG. **10**A to FIG. **10**D, the liquid state refrigerant is supplied from the liquid supply use channel etc. to the left and right direction of the sheet surface (x-direction). Note that, FIG. **10**A is a diagram corresponding to the embodiment shown in FIG. **2**A to FIG. **2**C.

[0129] In the modification of FIG. **10**B, in addition to the groove portions **40**, a plurality of groove portions **96** extending in a direction perpendicular to the groove portions **40** are provided. By these groove portions **96**, the liquid state refrigerant becomes easy to spread also in the direction in which the groove portions **96** are extended, and the liquid film becomes easy to be formed over the entire heat removal use channel. In particular, in a case where the supply positions of the liquid state refrigerant are separated from each other, for example, the case where the liquid state refrigerant is supplied from communicating holes formed in the liquid supply use channel, the refrigerant easily is depleted between the supply positions. However, the liquid state refrigerant is spread also between the supply positions by the groove portions **96**, therefore depletion is prevented.

[0130] Note that it is also possible to provide only the groove portions **96** without providing the groove portions **40** or possible to provide groove portions obliquely extending with respect to the flow direction and spread the liquid state refrigerant to both of the flow direction and the direction perpendicular to the channel by the groove portions. Zigzag groove portions may be provided as well. Note that the groove portions **40** or groove portions obliquely extending with respect to the channel are examples of groove portions traversing the channel. The groove portions traversing the channel may be ones extended from one sideward end of the channel to the other sideward end or may be ones extended within an appropriate range in the middle between sideward ends.

[0131] In the modification of FIG. **10**C, a net shaped sheet **98** is adhered to the inner circumferential surface of the heat removal use channel. The sheet **98** is an example of the sheet permeated with the liquid state refrigerant of the present invention. The sheet **98** is formed by, for example, a metal, ceramic, plastic, or fiber. The size and knitted form of the mesh may be appropriately selected in accordance with the type of the refrigerant etc. In this modification, the refrigerant is sucked into the sheet **98** and spreads on the inner circumferential surface of the heat removal use channel. Due to this, the liquid film is evenly formed over the entire inner circumferential surface.

[0132] In the modification of FIG. **10**D, a sheet **100** formed by a porous member is adhered to the inner circumferential surface of the heat removal use channel. The sheet **100** is an example of a sheet permeated with the liquid state refrigerant of the present invention. The sheet **100** is constructed by for example a sintered metal. In the sheet **100** as well, the same effect as that of the sheet **98** is obtained.

[0133] In place of the arrangement of the sheet **100**, the inner circumferential surface of the heat removal use channel may be coated, polished, or otherwise roughened so as to roughen the inner circumferential surface and give a liquid film retention function.

[0134] FIG. **10**E and FIG. **10**F show examples of the cross-sectional shapes of the groove portions **40** and groove portions **96**. The groove portions **102** shown in FIG. **10**E have V-shaped cross-sections, while groove portions **103** shown in FIG. **10**F have rectangular cross-sections. FIG. **10**E and FIG. **10**F are examples. The groove portions **40** and groove portions **96** may be given a U-shape or other various shapes as well.

[0135] FIG. **11**A to FIG. **11**C show a modification of extension of the heat removal use channel to the width direction of the channel, in which FIG. **11**A is a perspective view of an outer appearance of a heat removal portion **105**, FIG. **11**B is a cross-sectional view taken along an XIb-XIb arrow direction of FIG. **11**A, and FIG. **11**C is a cross-sectional view taken along an XIc-XIc arrow direction of FIG. **11**A.

[0136] In the heat removal portion **105** in FIG. **11**A to FIG. **11**C, pipes **107**A, **107**B, and **107**C (hereinafter, simply referred to as "pipes **107**", these sometimes not discriminated) having branch portions are inserted in a rectangular cross-section hollow body **106** at the two sides and center to separate it into sections where by two heat removal use channels **109**A and **109**B (hereinafter, simply referred to as "heat removal use channels **109**", these sometimes not discriminated) are formed. Further, in the pipes **107**A, **107**B, and **107**C, liquid supply use channels **110**A, **110**B, and **110**C (hereinafter, simply referred to as "liquid supply use channels **110**", these sometimes not discriminated) are formed in their internal portions. The pipes **107** are provided with a plurality of not shown communicating holes communicating the heat removal use channels **109** and the liquid supply use channels **110** along the flow direction of the heat removal use channels **109**.

[0137] In the each heat removal use channel **109**, in the same way as the heat removal use channels shown in FIG. **2**A etc., the liquid state refrigerant is supplied from the liquid supply use channels **110** arranged on the two sides of the heat removal use channel **109** via not shown communicating holes, whereby a liquid film of the refrigerant is formed. Note, the liquid supply use channel **110**B at the center supplies the liquid state refrigerant to both of the heat removal use channels **109**A and **109**B on the two sides thereof. The gas state refrigerant evaporated in the heat removal use channels **109** is discharged from the heat removal use channels **109**, then merged.

[0138] In the modification of FIG. **11**A to FIG. **11**C, the heat removal use channel is divided into a plurality of heat removal use channels **109** in the width direction of the channel, therefore the heating length in the width direction becomes shorter, and the depletion of the liquid state refrigerant is prevented. In other words, it becomes possible to extend the heat removal use channel to the width direction. In the two heat removal use channels **109**A and **109**B, the liquid supply use channel **110**B is shared, so the number of parts is decreased. The two heat removal use channels **109**A and **109**B are partitioned by the liquid supply use channel **110**B, so the influences of the heat removal use channels **109**A and **109**B on each other are eased.

[0139] FIG. **12**A to FIG. **12**C show a modification wherein the heat removal use channel is enlarged in the flow direction, in which FIG. **12**A is a perspective view of the outer appearance of a heat removal portion **112**, FIG. **12**B is a cross-sectional view taken along an XIIb-XIIb arrow direction of FIG. **12**A, and FIG. **12**C is a cross-sectional view taken along an XIIc-XIIc arrow direction of FIG. **12**A.

[0140] In the heat removal portion **112** in FIG. **12**A to FIG. **12**C, pipes **115**A, **115**B, and **115**C (hereinafter, simply referred to as "pipes **115**", these sometimes not discriminated) having pluralities of branch portions are inserted in a rectangular cross-section hollow body **114** at the two sides and center to separate it into sections where by two heat removal use channels **116**A and **116**B (hereinafter, simply referred to as "heat removal use channels **116**", these sometimes not discriminated) are formed. Further, in the pipes **115**A, **115**B, and **115**C, liquid supply use channels **117**A, **117**B, **117**C (hereinafter, simply referred to as "liquid supply use channels **118**", these sometimes not discriminated) are formed in their internal portions. The pipes **115** are provided with a plurality of not shown communicating holes communicating the heat removal use channels **116** and the liquid supply use channels **117** along the flow direction of the heat removal use channels **116**.

[0141] The heat removal use channels **116** are partitioned into pluralities of sections D**1**, D**2**, and D**3** in the flow direction (y-direction). The plurality of sections D**1** to D**3** are provided with discharge ports **119**A, **119**B, and **119**C which are opened sideward in the channels, for example, to the opposite side of the heat removal object HO, to discharge the refrigerant in the gas state. In each section, a liquid film is formed by the refrigerant supplied from the liquid supply use channels **117**, and the evaporated refrigerant is discharged from discharge ports **119**A to **119**C. Note that, the liquid supply use channels **117** may be communicated over all sections D**1** to D**3** as shown in FIG. **12**B, or may be partitioned into pluralities of sections in the same way as the heat removal use channels **116**.

[0142] In this modification, by partitioning the heat removal use channels **116** in the flow direction, the heat removal efficiency of the sections D**1** to D**3** is raised by enabling the discharge of the evaporated refrigerant in an early period, and the influences of the sections on each other can be eased. In other words, the heat removal use channel, i.e., heat removal surface, can be made long without limit. In addition, it is not necessary to partition the liquid supply use channels **117** matching with the sections D**1** to D**3**, so no design change is required. Note that, in the technique of running the liquid state refrigerant as in the conventional case, the pressure loss was large if the heat removal use channel was partitioned in the flow direction, the load of the pump increased, and also a drop of the cooling efficiency was caused, therefore the extension to the flow direction was difficult.

[0143] FIG. **13** is a diagram showing a modification of the overall construction of the heat removal apparatus. Note that the same notations are attached to common portions to those of the heat removal apparatus **1** of FIG. **1**. In the heat removal apparatus of FIG. **13**, the gas and liquid phase separator **19** and the subcooling portion **21** are omitted. Accordingly, the evaporated refrigerant completely returns to the liquid inside the condensation portion **14**, and the heat quantity Q from the heat removal object will be completely released to the atmosphere in the condensation portion **14**.

[0144] FIG. **17** is a diagram showing an example of application of the present invention.

[0145] An automobile **151** has a power controller **153** as the heat removal object and a heat removal apparatus **155**.

[0146] The heat removal apparatus **155** has a construction resembling that of the heat removal apparatus **1** explained above. Specifically, the heat removal apparatus **155** has an auxiliary liquid tank **157** (corresponding to the storage tank **3**) storing the liquid state refrigerant, a pump **159** (corresponding to the pump **5**) pumping out the liquid state refrigerant, a heat removal portion **161** (corresponding to the heat removal portion **12**) removing the heat of the power controller **153** by the liquid state refrigerant pumped out by the pump **159**, a radiator **163** (corresponding to the condensation portion **14**) condensing the gas state refrigerant flowing out of the heat removal portion **161**, and a gas and liquid phase separator **165** (corresponding to the gas and liquid phase separator **19**) separating the refrigerant flowing out of the radiator **163** to the gas state refrigerant and the liquid state refrigerant. The liquid state refrigerant separated by the gas and liquid phase separator **165** is pumped out by the pump **159**. The liquid state refrigerant pumped out by the pump **159** is controlled in the flow rate to the auxiliary liquid tank **157** and heat removal portion **161** by a flow rate control unit **160**.

[0147] The heat removal portion **161** has, although not particularly shown, a heat removal use channel provided adjacent to the power controller **153** in the same way as the heat removal portion **12**. At a plurality of positions (within a predetermined range) in a predetermined direction of the heat removal use channel, the liquid state refrigerant is supplied into the heat removal use channel, whereby a liquid film of the refrigerant is formed over the plurality of positions (predetermined range) on the inner circumferential surface of the heat removal use channel. The power controller **153** is cooled by the evaporation of the liquid film.

[0148] At the time of application to an automobile, the temperature difference between a permissible temperature of the power controller (about 100° C.) and a temperature of open air to which a waste heat is released (about 30° C.) is small, and the required temperature difference of the heat removal portion can be kept smaller than that by the usual boiling cooling by liquid film evaporation, therefore the heat removal capability of the overall cooling system can be raised.

[0149] FIG. **18** is a diagram showing another example of application of the present invention.

[0150] A power transformation system **171** is a system provided in, for example, a generating station or factory for transforming voltage etc. The power transformation system **171** has a plurality of power elements **173** as the heat removal object and a heat removal apparatus **175**.

[0151] The heat removal apparatus **175** has a construction resembling that of the heat removal apparatus **121** explained above. Specifically, the heat removal apparatus **175** has a pump **177** (corresponding to the pump **5**) pumping out the liquid state refrigerant, a plurality of heat removal portions **179** (corresponding to the heat removal portion **12**) removing the heat of the plurality of power elements **173** by the liquid state refrigerant pumped out by the pump **177**, and an air cooling unit **181** (corresponding to the condensation portion **14**) condensing the gas state refrigerant flowing out of the heat removal portions **179**. The refrigerant flowing out of the air cooling unit **181** is pumpede out by the pump **177**.

[0152] The plurality of power elements **173** and plurality of heat removal portions **179** construct a power element cooling train **183** by alternately stacking of one heat removal portion **179** and two power elements **173**. A plurality of power element cooling trains **183** are thereby provided. In each power element cooling train **183**, power elements **173** are arranged on both sides of one heat removal portion **179**, so heat removal of two power elements **173** by one heat removal portion **179** becomes possible.

[0153] The plurality of power element cooling trains **183** and the plurality of heat removal portions **179** in the power element cooling trains **183** are connected parallel to each other. Namely, the heat removal apparatus is constructed so that the liquid state refrigerant pumped out from the pump **177** is separated and flows into each power element cooling train **183** and is further separated in each power element cooling train **183** and flows to each heat removal portion **179**.

[0154] Each heat removal portion **179** has, although not particularly shown, a heat removal use channel provided adjacent to the power element **173** in the same way as the heat removal portion **12**. At a plurality of positions (within a predetermined range) in a predetermined direction of the heat removal use channel, the liquid state refrigerant is supplied into the heat removal use channel, whereby a liquid film of the refrigerant is formed over the plurality of positions (predetermined range) on the inner circumferential surface of the heat removal use channel. The power element **173** is cooled by the evaporation of the liquid film.

[0155] FIG. **19**A and FIG. **19**B are graphs explaining effects of the present invention. FIG. **19**A is a graph showing a heat transmission characteristic obtained by experiments in the heat removal apparatus of an example of the present invention. FIG. **19**B is a graph showing the heat transmission characteristic of FIG. **19**A in comparison with the heat transmission characteristic in the prior art. In FIG. **19**A and FIG. **19**B, the abscissas indicate temperature differences ΔT (K) between the heat removal object surface (one surface constructing the heat removal use channel) of the heat removal object and the liquid state refrigerant flowing into the heat removal use channel, while the ordinates indicate heat fluxes q (W/cm^2) on the heat removal object surface of the heat removal object. Further, heat transmission ratios a (W/m^{2}K) are shown in graphs.

[0156] In FIG. **19**A and FIG. **19**B, circular marks M**1** indicate values at the upstream position in the flow direction and the center position in the width direction of the heat removal use channel in the heat removal apparatus as an example of the present invention, rectangular marks M**2** indicate values at the center position in the flow direction and the center position in the width direction of the heat removal use channel in the heat removal apparatus as an example of the present invention, and triangular marks M**3** indicate values at the downstream position in the flow direction and the center position in the width direction of the heat removal use channel in the heat removal apparatus as an example of the present invention.

[0157] In the heat removal use channel of the heat removal apparatus as an example of the present invention, grooves are formed in the inner circumferential surface. Further, a heat spreader is not provided. The subcooling of the liquid (difference from the saturation temperature) at an inlet of the heat removal use channel is 15K. A volume flow rate of the liquid refrigerant is 4.5 liters/min. One side of the liquid supply use channel is closed. A void width (clearance between the heat removal object surface and the facing heat insulation surface) of the heat removal use channel is 5 mm. The width of the heat removal use channel×length (flow direction) is 30 mm×150 mm.

[0158] As understood from FIG. **19**A and FIG. **19**B, in the heat removal apparatus of the example of the present invention, even in the case where a heat spreader is not provided, cooling with a heat flux higher by 1 order than that by the water cooling system equipped with a heat spreader is accomplished. In addition, a heat generating area which can be cooled is larger by 2 orders, and a high heat transmission ratio is obtained by the liquid film evaporation, therefore the temperature difference between the heat removal object surface and the fluid is sufficiently small.

[0159] The present invention is not limited to the above embodiments and modifications and may be executed in various ways.

[0160] The heat removal object need only have a higher temperature than the saturation temperature of the refrigerant, may be a heat generating object releasing heat such as a power element, motor, or battery, or may be a heat transmission object transmitting the heat of a heat generating object such as a heat spreader. It may be any of a gas, liquid, or solid.

[0161] The heat removal use channel may be formed by using an appropriate material, shape, and dimensions so far as it is provided adjacent to the heat removal object. Whatever the case, the heat is transmitted to the heat removal use channel from the heat removal object so far as the heat removal use channel is adjacent to the heat removal object. This means that the channel is thermally connected to the heat removal object.

[0162] The plurality of positions at which the supply of the liquid state refrigerant to the heat removal use channel is made are not limited to ones aligned in the flow direction. So far as the liquid state refrigerant is supplied to the plurality of positions and a liquid film is formed over the plurality of positions, the plurality of positions may be provided in a direction perpendicular to the channel as well. Note that, it is preferable that a portion where the depletion of liquid occurs is not formed within the range over the plurality of positions. However, even if the depletion occurs at a portion, it can be said that a liquid film is formed over the plurality of positions if the liquid state refrigerant is supplied to the plurality of positions, and a state where the liquid state refrigerant is filled in the range over the plurality of positions (the liquid state refrigerant is filled in the heat removal use channel) as in the conventional technique of running the liquid state refrigerant is not exhibited.

1. A heat removal method comprising removing heat of a heat removal object by supplying a liquid state refrigerant into a heat removal use channel, which is provided to extend along the heat removal object and has a longer channel length than width of a surface along the heat removal object, from an opening, which opens towards inside of the heat removal use channel in a side wall of the heat removal channel at a side of a plate shaped member forming the surface along the heat removal object of the heat removal use channel and abutting against the heat removal object, in a predetermined range in the flow direction of the heat removal use channel, forming a liquid film of the refrigerant over the predetermined range on the inside surface of the plate shaped member, making the liquid film evaporate by the heat from the heat removal object, and discharging the evaporated refrigerant from the heat removal use channel.

2. A heat removal method as set forth in claim **1**, supplying the liquid state refrigerant at a plurality of positions over the predetermined range.

3. A heat removal method comprising removing heat of a heat removal object by supplying a liquid state refrigerant into a heat removal use channel, which is provided adjacent to the heat removal object, in a predetermined range of a flow direction of said heat removal use channel, forming a liquid film of the refrigerant over the predetermined range on an inside surface of a plate shaped member forming said heat removal use channel and abutting against the heat removal object, making the liquid film evaporate by the heat from the heat removal object, and discharging the evaporated refrigerant from the heat removal use channel, wherein

In said supplying the liquid state refrigerant into the heat removal use channel, the refrigerant is supplied from an opening formed at an outer circumference, which sticks out into the heat removal use channel toward the plate shaped member, of a liquid supply channel, which extends along the heat removal channel, and opening towards inside surface of the plate shaped member.

4. A heat removal apparatus comprising:

a heat removal use channel provided to extend along a heat removal object and having a longer channel length than width of a surface along the heat removal use channel; and

a liquid supply portion constructed to supply a liquid state refrigerant into the heat removal use channel from an opening, which opens towards inside of the heat removal use channel in a side wall of the heat removal channel at a side of a plate shaped member forming the surface along the heat removal object of the heat removal use channel and abutting against the heat removal object, in a predetermined range in the flow direction of the heat removal use channel, form a liquid film of the refrigerant over the predetermined range on the inside surface of the plate shaped member, make the liquid film evaporate by the heat from the heat removal object, and discharge the evaporated refrigerant from the heat removal use channel.

5. A heat removal apparatus as set forth in claim **4**, wherein the opening opens at a position nearer the plate shaped member than the surface of the heat removal use channel facing the plate shaped member.

6. A heat removal apparatus as set forth in claim **4**, wherein said opening is provided at each of two side walls facing each other, and

said liquid supply portion can also supply the liquid state refrigerant from a second opening, which opens towards the plate shaped member, of a projecting part projecting out from a surface facing the plate shaped member of the heat removal use channel toward the plate shaped member between the two side walls.

7. A heat removal apparatus as set forth in claim **4**, wherein a mass ratio of a flow rate of the evaporated refrigerant with respect to the total flow rate of the refrigerant in the heat removal use channel is equal to or larger than 0.2.

8. A heat removal apparatus as set forth in claim **7**, comprising:

a control unit controlling a rate of supply of the liquid state refrigerant to the heat removal use channel to approach a target value set so that the mass ratio becomes equal to or larger than 0.2.

9. A heat removal apparatus as set forth in claim **4**, wherein the liquid supply portion supplies the liquid state refrigerant at a plurality of positions over the predetermined range.

10. A heat removal apparatus as set forth in claim **4**, wherein the liquid supply portion has a liquid supply use channel which extends along said heat removal use channel at a side of the plate shaped member and is partitioned from said heat removal use channel by said side wall, and the opening is constructed to allow passage of the liquid state refrigerant from the liquid supply use channel to the heat removal use channel.

11. A heat removal apparatus as set forth in claim **4**, wherein the heat removal use channel is partitioned to a plurality of sections in the flow direction, and the plurality of sections each are provided with discharge ports discharging the gas state refrigerant.

12. A heat removal apparatus as set forth in claim **4**, wherein the heat removal use channel has discharge ports of the refrigerant provided at both ends in the flow direction.

13. A heat removal apparatus as set forth in claim **4**, wherein the inside surface of the plate shaped member is provided with groove portions to which the liquid state refrigerant is stuck by surface tension to spread the film of the refrigerant to the inside surface.

14. A heat removal apparatus as set forth in claim **13**, wherein the groove portions extend in a direction traversing the heat removal use channel.

15. A heat removal apparatus as set forth in claim **13**, wherein the groove portions extend in a direction along the heat removal use channel.

16. A heat removal apparatus as set forth in claim **4**, wherein the inside surface of the plate shaped member is lined by a sheet through which the liquid state refrigerant can permeate and spreading the film of the refrigerant to the inside surface.

17. A heat removal apparatus as set forth in claim **4**, wherein the inside surface of the plate shaped member is roughened.

18. A heat removal apparatus comprising:

a heat removal use channel provided adjacent to a heat removal object; and

a liquid supply portion constructed to supply a liquid state refrigerant into the heat removal use channel in a predetermined range of a flow direction of the heat removal use channel and form a liquid film of the refrigerant over the predetermined range at an inside surface of a plate shaped member forming the heat removal use channel and abutting against said heat removal object, wherein

said liquid supply portion has a liquid supply use channel extending along said heat removal use channel, having an outer circumference sticking out into the heat removal use channel toward the plate shaped member, being formed with an opening which opens toward the plate shaped member in the outer circumference, and supplying liquid state refrigerant from the opening to the heat removal use channel.

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