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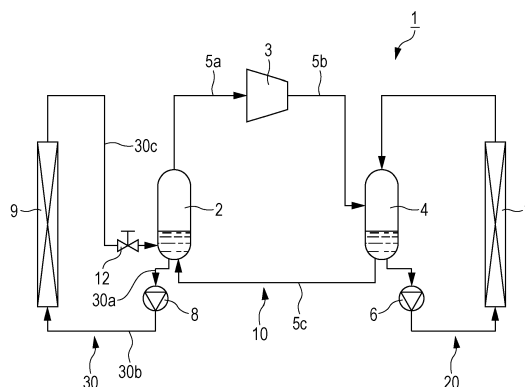
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(54) **Refrigeration-cycle equipment**

(57) The disclosed refrigeration-cycle equipment comprises a main circuit and an evaporation-side circulation circuit. The main circuit includes i) a compressor that compresses refrigerant vapor, ii) a condensation mechanism that condenses the refrigerant vapor, and iii) an evaporative mechanism that stores refrigerant liquid and that evaporates the refrigerant liquid. The evaporation-side circulation circuit includes a heat exchanger for heat absorption and a decompression mechanism. The refrigerant returns to the evaporative mechanism after the refrigerant absorbing heat in the heat exchanger for heat absorption and the pressure of the refrigerant being reduced in the decompression mechanism. The refrigeration-cycle equipment further has an interaction mechanism that prevents droplets contained in the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being fed into the compressor.

FIG. 1



Description

BACKGROUND

1. Technical Field

[0001] The present disclosure relates to a refrigeration-cycle equipment.

2. Description of the Related Art

[0002] Hitherto, refrigeration-cycle equipment employing a Freon refrigerant or an alternative Freon refrigerant has been widely used. However, such a refrigerant has a problem of ozone layer depletion, global warming, and the like. Hence, refrigeration-cycle equipment employing an evaporative liquid, such as water, as a refrigerant that have little damage on the global environment has been proposed.

[0003] In Japanese Unexamined Patent Application Publication No. 2008-122012, vaporizing cooling equipment is disclosed as refrigeration-cycle equipment that includes an evaporator, a cooling point, a centrifugal compressor, a Roots compressor, and a condenser. The evaporator boils and evaporates an evaporative liquid, such as water, at a pressure that is lower than the atmospheric pressure. The water having been boiled and evaporated by the evaporator and whose temperature has thus dropped is pumped out by a circulating pump, is delivered to the cooling point through a duct, and returns into the evaporator through another duct.

[0004] If a refrigerant such as water is employed, a large amount of refrigerant vapor generated in an evaporative mechanism that evaporates the refrigerant at a pressure lower than the atmospheric pressure needs to be compressed at a high compression ratio. Accordingly, in the vaporizing cooling equipment disclosed by Japanese Unexamined Patent Application Publication No. 2008-122012, the centrifugal compressor and the Roots compressor are connected in series, whereby refrigerant vapor that has been compressed by the centrifugal compressor is further compressed by the Roots compressor. In the refrigeration-cycle equipment disclosed by Japanese Unexamined Patent Application Publication No. 2008-122012, the state of the refrigerant that returns to the evaporator is not considered at all.

SUMMARY

[0005] The present disclosure provides refrigeration-cycle equipment in which a compressor may have an extended life with a consideration for the state of a refrigerant that returns to an evaporative mechanism.

[0006] Refrigeration-cycle equipment according to the present disclosure includes a main circuit and an evaporation-side circulation circuit. The main circuit includes i)a compressor that compresses refrigerant vapor, ii)a condensation mechanism that condenses the refrigerant

vapor, and iii)an evaporative mechanism that stores refrigerant liquid and that evaporates the refrigerant liquid. The evaporation-side circulation circuit includes a heat exchanger for heat absorption and a decompression mechanism. The refrigerant returns to the evaporative mechanism after the refrigerant absorbing heat in the heat exchanger for heat absorption and the pressure of the refrigerant being reduced in the decompression mechanism. The refrigeration-cycle equipment further has an interaction mechanism that prevents droplets contained in the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being fed into the compressor.

[0007] In the above refrigeration-cycle equipment, the interaction mechanism prevents droplets contained in the refrigerant having undergone pressure reduction in the decompression mechanism and having returned to the evaporative mechanism from being fed into the compressor. Thus, the life of the compressor can be extended.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Fig. 1 is a diagram of refrigeration-cycle equipment according to an embodiment;

Fig. 2A is a vertical sectional view illustrating an evaporative mechanism and an interaction mechanism according to the embodiment;

Fig. 2B is a vertical sectional view illustrating the evaporative mechanism and another interaction mechanism according to the embodiment;

Fig. 3 is a perspective view illustrating an interaction mechanism according to a first modified example;

Fig. 4 is a cross sectional view illustrating the interaction mechanism according to the first modified example;

Fig. 5A is a vertical sectional view illustrating a case of a second modified example employing a discharge preventing wall;

Fig. 5B is a vertical sectional view illustrating another case of the second modified example;

Fig. 5C is a vertical sectional view illustrating yet another case of the second modified example;

Fig. 6 is a vertical sectional view illustrating a third modified example employing a partition wall;

Fig. 7 is a vertical sectional view illustrating a case of a fourth modified example employing a discharge

preventing mechanism;

Fig. 8 is a vertical sectional view illustrating another case of the fourth modified example;

Fig. 9 is a vertical sectional view illustrating yet another case of the fourth modified example;

Fig. 10 is a vertical sectional view illustrating yet another case of the fourth modified example;

Fig. 11 is a diagram illustrating exemplary refrigeration-cycle equipment including the discharge preventing mechanism illustrated in Fig. 10;

Fig. 12 is a vertical sectional view illustrating yet another case of the fourth modified example;

Fig. 13 is a vertical sectional view illustrating yet another case of the fourth modified example;

Fig. 14 is a vertical sectional view illustrating yet another case of the fourth modified example;

Fig. 15 is a vertical sectional view illustrating a case of a fifth modified example employing an evaporative mechanism;

Fig. 16 is a vertical sectional view illustrating another case of the fifth modified example;

Fig. 17 is a vertical sectional view illustrating yet another case of the fifth modified example;

Fig. 18 is a vertical sectional view illustrating a case of a sixth modified example employing an interaction mechanism;

Fig. 19 is a vertical sectional view illustrating another case of the sixth modified example;

Fig. 20 is a vertical sectional view illustrating a seventh modified example employing a baffle plate;

Fig. 21 is a vertical sectional view illustrating another case of the seventh modified example;

Fig. 22 is a vertical sectional view illustrating yet another case of the seventh modified example;

Fig. 23 is a vertical sectional view illustrating yet another case of the seventh modified example; and

Fig. 24 is a longitudinal sectional view of an ejector as a condensation mechanism.

DETAILED DESCRIPTION

Knowledge as Grounds for Present Disclosure

5 **[0009]** In the refrigeration-cycle equipment disclosed by Japanese Unexamined Patent Application Publication No. 2008-122012, the cooling point corresponds to, for example, a heat exchanger. In such a case, when cooling is performed by pumping the refrigerant liquid out of the evaporator with a supply pump and supplying the refrigerant liquid to the heat exchanger as the cooling point through the duct, the refrigerant liquid may evaporate in the heat exchanger as the cooling point. If the refrigerant liquid evaporates in the heat exchanger as the cooling point, it becomes difficult to supply the refrigerant liquid in the evaporator to the heat exchanger by using the supply pump. Hence, a decompression mechanism may be provided in the duct through which the refrigerant that has passed the cooling point returns into the evaporator. Thus, the refrigerant liquid is prevented from evaporating in the heat exchanger as the cooling point.

[0010] The refrigerant whose pressure has been reduced by the decompression mechanism returns into the evaporator. In this step, refrigerant liquid droplets may be generated. If such droplets in the evaporator are taken into the compressor, the droplets may damage components of the compressor. Consequently, the life of the compressor may be reduced. Such a problem becomes particularly serious in a case where the size of the evaporator is reduced or the duct that connects the evaporator and the compressor is shortened in response to demands for size reduction.

[0011] In view of the above, the present inventors have reached the invention having the following aspects.

35 **[0012]** Refrigeration-cycle equipment according to a first aspect of the present disclosure includes a main circuit through which a refrigerant is circulated, whose saturated vapor pressure of the refrigerant at room temperature being a negative pressure circulates, the main circuit including i) a compressor that compresses refrigerant vapor, ii) a condensation mechanism that condenses the refrigerant vapor, and iii) an evaporative mechanism that stores refrigerant liquid and that evaporates the refrigerant liquid, i) the compressor, ii) the condensation mechanism, and iii) the evaporative mechanism being connected to one another in that order; an evaporation-side circulation circuit that includes a heat exchanger for heat absorption and includes a decompression mechanism, the refrigerant liquid stored in the evaporative mechanism being supplied to the heat exchanger for heat absorption through the evaporation-side circulation circuit, the refrigerant returning to the evaporative mechanism after the refrigerant absorbing heat in the heat exchanger for heat absorption and the pressure of the refrigerant being reduced in the decompression mechanism; and the refrigerant having absorbed heat in the heat exchanger for heat absorption and being at a pressure higher than a pressure in the evaporative mechanism under-

goes pressure reduction in the decompression mechanism and returns to the evaporative mechanism; and an interaction mechanism that prevents droplets contained in the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being fed into the compressor.

[0013] According to the first aspect, the interaction mechanism prevents the droplets contained in the refrigerant having undergone pressure reduction in the decompression mechanism and having returned to the evaporative mechanism from being fed into the compressor. Thus, the life of the compressor can be extended.

[0014] According to a second aspect, for example, the decompression mechanism included in the refrigeration-cycle equipment according to the first aspect may be a valve, a nozzle, or a capillary tube.

[0015] According to a third aspect, for example, the interaction mechanism included in the refrigeration-cycle equipment according to the first or second aspect may be a connection portion that is provided to the evaporative mechanism and that connects the evaporative mechanism and the evaporation-side circulation circuit, to return the refrigerant having absorbed heat in the heat exchanger for heat absorption into the refrigerant liquid stored in the evaporative mechanism. The connection portion included in the refrigeration-cycle equipment according to the first or second aspect may extend through a wall of the evaporative mechanism into an internal space of the evaporative mechanism, and an end of the connection portion may be positioned below a surface of the refrigerant liquid stored in the evaporative mechanism. In other words, according to the third aspect, the interaction mechanism according to the first or second aspect may be, for example, a connection portion for the evaporation-side circulation circuit, the connection portion being connected to the evaporative mechanism such that the refrigerant having absorbed heat in the heat exchanger for heat absorption returns into the refrigerant liquid stored in the evaporative mechanism. The connection portion included in the refrigeration-cycle equipment according to the first or second aspect may extend through the wall of the evaporative mechanism into the internal space of the evaporative mechanism, with the end of the connection portion being positioned below the surface of the refrigerant liquid stored in the evaporative mechanism. According to the third aspect, even if any droplets are generated in the refrigerant returning to the evaporative mechanism, the droplets are taken into the refrigerant liquid stored in the evaporative mechanism. Therefore, the droplets of the refrigerant liquid are prevented from being fed into the compressor. That is, the connection portion extends through the wall of the evaporative mechanism up to a position in the internal space of the evaporative mechanism, with the end of the connection portion being positioned below the surface of the refrigerant liquid stored in the evaporative mechanism. Such a configuration reduces the probability that bubbles that have been generated by the refrigerant vapor contained in the re-

frigerant flowing through the connection portion and have returned into the evaporative mechanism may be supplied into the evaporation-side circulation circuit. Accordingly, the probability that the refrigerant flowing through the heat exchanger for heat absorption may contain bubbles is reduced. Therefore, the heat exchanging efficiency of the heat exchanger for heat absorption and the efficiency (coefficient of performance, abbreviated to COP) of the refrigeration-cycle equipment are increased. Such knowledge comes from findings made by the present inventors that the efficiency of the refrigeration-cycle equipment configured to allow the refrigerant having absorbed heat in the heat exchanger for heat absorption to return into the refrigerant liquid stored in the evaporative mechanism is lower than the efficiency of refrigeration-cycle equipment configured to allow a refrigerant having absorbed heat in a heat exchanger for heat absorption to return to a position above the surface of a refrigerant liquid stored in an evaporative mechanism. This knowledge is novel and is not found in the known art.

[0016] According to a fourth aspect, for example, the internal space of the evaporative mechanism included in the refrigeration-cycle equipment according to the third aspect may have a column shape, and a virtual line extending from the connection portion into the evaporative mechanism may be off a center of the internal space having the column shape. In other words, according to the fourth aspect, the internal space of the evaporative mechanism according to the third aspect may have a column shape, and the connection portion may be connected to the evaporative mechanism such that the flow of the refrigerant that has returned from the evaporation-side circulation circuit to the evaporative mechanism has a velocity component in a spiral circumferential direction of the internal space. According to the fourth aspect, the refrigerant having returned into the evaporative mechanism flows in the spiral circumferential direction of the internal space of the evaporative mechanism in the refrigerant liquid stored in the evaporative mechanism. Thus, the refrigerant swirls in the refrigerant liquid stored in the evaporative mechanism. Therefore, even if the refrigerant returning to the evaporative mechanism contains refrigerant liquid droplets, the droplets in the refrigerant and the refrigerant vapor are separated from each other under a centrifugal force. Consequently, the refrigerant liquid droplets are prevented from being fed into the compressor.

[0017] According to a fifth aspect, for example, the refrigeration-cycle equipment according to the third or fourth aspect may further include a discharge preventing wall provided above the connection portion, the discharge preventing wall preventing a flow of the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism. According to the fifth aspect, since the flow of the refrigerant having returned to the evaporative mechanism is prevented from being dis-

charged from the surface of the refrigerant liquid stored in the evaporative mechanism, refrigerant liquid droplets generated by the disturbance of the surface of the refrigerant liquid stored in the evaporative mechanism are prevented from being fed into the compressor.

[0018] According to a sixth aspect, for example, the refrigeration-cycle equipment according to any one of the third to fifth aspects may further include a partition wall provided in the evaporative mechanism and between an outlet and a return port, through which the refrigerant liquid stored in the evaporative mechanism being supplied to the evaporation-side circulation circuit through the outlet, the return port being provided by the connection portion and through which the refrigerant returning to the evaporative mechanism through the return port. According to the sixth aspect, the partition wall prevents the refrigerant vapor having returned to the evaporative mechanism through the return port from flowing out of the evaporative mechanism through the outlet to the evaporation-side circulation circuit.

[0019] According to a seventh aspect, for example, the connection portion included in the refrigeration-cycle equipment according to the third aspect may include a discharge preventing mechanism that prevents a flow of the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism.

[0020] According to the seventh aspect, the discharge preventing mechanism prevents the flow of the refrigerant having returned to the evaporative mechanism through the connection portion from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism. Therefore, refrigerant liquid droplets generated by the disturbance of the surface of the refrigerant liquid stored in the evaporative mechanism are prevented from being fed into the compressor.

[0021] According to an eighth aspect, for example, the discharge preventing mechanism included in the refrigeration-cycle equipment according to the seventh aspect may include a widened portion positioned above a bottom of the evaporative mechanism and forming a passage, cross sectional area of the passage increasing in a direction of the flow of the refrigerant in the connection portion. According to the eighth aspect, the speed of the refrigerant flowing through the connection portion is reduced in the passage provided by the widened portion. Therefore, the flow of the refrigerant having returned to the evaporative mechanism through the connection portion is prevented from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism.

[0022] According to a ninth aspect, for example, the connection portion included in the refrigeration-cycle equipment according to the eighth aspect may further include an extended portion extending upward from the widened portion and forming a passage, cross sectional area of passage being constant in the direction of the

flow of the refrigerant in the connection portion. According to the ninth aspect, in the passage provided by the extended portion, the sizes of bubbles generated by the refrigerant vapor contained in the refrigerant flowing through the connection portion are adjusted. Hence, such bubbles are prevented from being supplied to the evaporation-side circulation circuit after returning to the evaporative mechanism.

[0023] According to a tenth aspect, for example, the discharge preventing mechanism included in the refrigeration-cycle equipment according to the eighth or ninth aspect may further include a flow distributing plate, a central axis of the connection portion passing through the flow distributing plate, the flow distributing plate having a plurality of through holes. Furthermore, a sum of opening areas corresponding to the respective through holes may be larger than a cross sectional area of a passage that is provided by the connection portion and is positioned on an upstream side with respect to the widened portion in the direction of the flow of the refrigerant in the connection portion.

[0024] According to the tenth aspect, the flow distributing plate reduces the spatial variation in the speed of the refrigerant flowing through the connection portion and returning to the evaporative mechanism. Furthermore, the sum of the opening areas of the respective through holes is larger than the cross sectional area of the passage provided by the connection portion and positioned on the upstream side with respect to the widened portion. Therefore, the speed of the refrigerant flowing through the plurality of through holes is prevented from becoming too high.

[0025] According to an eleventh aspect, for example, the discharge preventing mechanism included in the refrigeration-cycle equipment according to any one of the eighth to tenth aspects may further include a porous member provided such that a central axis of the connection portion passes through the porous member. According to the eleventh aspect, the widened portion and the porous member decelerate the flow of the refrigerant returning from the connection portion to the evaporative mechanism and reduce the spatial variation in the flow speed of the refrigerant.

[0026] According to a twelfth aspect, for example, the discharge preventing mechanism included in the refrigeration-cycle equipment according to any one of the eighth to tenth aspects may further include a narrowed portion projecting in such a manner as to be narrowed in a direction opposite to the direction of the flow of the refrigerant in the connection portion, the narrowed portion having a tip positioned on a central axis of the connection portion. According to the twelfth aspect, the flow of the refrigerant is evenly distributed by the narrowed portion. Moreover, while the refrigerant is flowing, the occurrence of flow separation (the generation of vortices) is suppressed. Therefore, the pressure loss in the flow of the refrigerant is small.

[0027] According to a thirteenth aspect, for example,

the connection portion included in the refrigeration-cycle equipment according to any one of the seventh to twelfth aspects may extend vertically upward. According to the thirteenth aspect, the flow of the refrigerant is decelerated under the gravitational force acting on the refrigerant flowing in the connection portion.

[0028] According to a fourteenth aspect, for example, the decompression mechanism included in the refrigeration-cycle equipment according to the ninth aspect may be a valve. Furthermore, the refrigeration-cycle equipment according to the ninth aspect may further include a heat-absorption-side temperature sensor that detects a temperature of the refrigerant having absorbed heat in the heat exchanger for heat absorption and returning to the evaporative mechanism; a refrigerant vapor temperature sensor that detects a temperature of the refrigerant vapor in the evaporative mechanism; a liquid level sensor that detects a level of the refrigerant liquid stored in the evaporative mechanism; and a control unit that controls the level of the refrigerant liquid stored in the evaporative mechanism by adjusting an opening degree of the valve on the basis of a value detected by the heat-absorption-side temperature sensor, a value detected by the refrigerant vapor temperature sensor, and a value detected by the liquid level sensor.

[0029] According to the fourteenth aspect, the level of the refrigerant liquid stored in the evaporative mechanism is controlled to an appropriate level on the basis of the temperature of the refrigerant having absorbed heat in the heat exchanger for heat absorption and returning to the evaporative mechanism, the temperature of the refrigerant vapor in the evaporative mechanism, and the level of the refrigerant liquid stored in the evaporative mechanism. For example, the level of the refrigerant liquid stored in the evaporative mechanism is controlled such that bubbles of the refrigerant vapor are generated above the upper end of the widened portion. That is, the level of the refrigerant liquid stored in the evaporative mechanism is controlled such that the refrigerant flows in a single phase (in a liquid phase) up to the upper end of the widened portion.

[0030] According to a fifteenth aspect, for example, the internal space of the evaporative mechanism included in the refrigeration-cycle equipment according to the third aspect may narrow toward a bottom of the evaporative mechanism. Furthermore, the connection portion may be connected to the bottom of the evaporative mechanism. According to the fifteenth aspect, the flow of the refrigerant having returned to the evaporative mechanism through the connection portion is decelerated in the internal space of the evaporative mechanism. Therefore, the flow of the refrigerant having returned to the evaporative mechanism through the connection portion is prevented from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism.

[0031] According to a sixteenth aspect, for example, the refrigeration-cycle equipment according to the fifteenth aspect may further include a flow distributing plate

provided in the internal space such that a central axis of the connection portion passes through the flow distributing plate, the flow distributing plate having a plurality of through holes. Furthermore, a sum of opening areas of the respective through holes may be larger than a cross sectional area of a passage provided by the connection portion. According to the sixteenth aspect, in the internal space of the evaporative mechanism, the flow distributing plate reduces the spatial variation in the speed of the flow of the refrigerant having returned to the evaporative mechanism through the connection portion. Moreover, since the sum of the opening areas of the respective through holes is larger than the cross sectional area of the passage provided by the connection portion, the speed of the flow of the refrigerant passing through the through holes is prevented from becoming too high.

[0032] According to a seventeenth aspect, for example, the refrigeration-cycle equipment according to fifteenth or sixteenth aspect may further include a narrowed portion projecting in the internal space in such a manner as to be narrowed toward the bottom of the evaporative mechanism, the narrowed portion having a tip positioned on a central axis of the connection portion. According to the seventeenth aspect, the flow of the refrigerant having returned to the evaporative mechanism through the connection portion is evenly distributed in the internal space of the evaporative mechanism by the narrowed portion. Moreover, while the refrigerant is flowing, the occurrence of flow separation (the generation of vortices) is suppressed. Therefore, the pressure loss in the flow of the refrigerant is small.

[0033] According to an eighteenth aspect, for example, the connection portion included in the refrigeration-cycle equipment according to any one of the fifteenth to seventeenth aspects may extend vertically upward. According to the eighteenth aspect, the flow of the refrigerant is decelerated under the gravitational force acting on the refrigerant flowing in the connection portion.

[0034] According to a nineteenth aspect, for example, the interaction mechanism included in the refrigeration-cycle equipment according to the first or second aspect may be a connection portion provided to the evaporative mechanism and connecting the evaporative mechanism and the evaporation-side circulation circuit to each other, the interaction mechanism allowing the refrigerant having absorbed heat in the heat exchanger for heat absorption to return into the refrigerant liquid stored in the evaporative mechanism. Furthermore, the connection portion may extend through a wall of the evaporative mechanism into an internal space of the evaporative mechanism, and an end of the connection portion may be positioned above a surface of the refrigerant liquid stored in the evaporative mechanism. Furthermore, the end of the connection portion may be oriented such that a flow of the refrigerant immediately after returning to the evaporative mechanism has a velocity component in a vertical direction. In other words, according to the nineteenth aspect, for example, the interaction mechanism include in the refrig-

eration-cycle equipment according to the first or second aspect may be a connection portion for the evaporation-side circulation circuit, the connection portion being connected to the evaporative mechanism such that the refrigerant returns to the evaporative mechanism from a position above the surface of the refrigerant liquid stored in the evaporative mechanism, the connection portion being connected to the evaporative mechanism such that the flow of the refrigerant immediately after returning to the evaporative mechanism has a velocity component in the vertical direction. According to the nineteenth aspect, refrigerant liquid droplets contained in the refrigerant having returned to the evaporative mechanism flow toward the surface of the refrigerant liquid stored in the evaporative mechanism. Consequently, the refrigerant liquid droplets contained in the refrigerant having returned to the evaporative mechanism are prevented from being fed into the compressor.

[0035] According to a twentieth aspect, for example, the interaction mechanism included in the refrigeration-cycle equipment according to the first or second aspect may include a connection portion for the evaporation-side circulation circuit, the connection portion being connected to the evaporative mechanism such that the refrigerant returns to the evaporative mechanism from a position above the surface of the refrigerant liquid stored in the evaporative mechanism; and a baffle plate that baffles a flow of the refrigerant having returned to the evaporative mechanism through the connection portion. According to the twentieth aspect, the baffle plate prevents the refrigerant liquid droplets contained in the refrigerant having returned to the evaporative mechanism from being fed into the compressor.

[0036] An embodiment of the present disclosure will now be described with reference to the accompanying drawings. The following description only relates to an exemplary embodiment of the present disclosure and does not limit the present disclosure.

Embodiment

[0037] As illustrated in Fig. 1, refrigeration-cycle equipment 1 includes a main circuit 10, a condensation-side circulation circuit 20, and an evaporation-side circulation circuit 30. The main circuit 10 includes a compressor 3, a condensation mechanism 4, and an evaporative mechanism 2. The compressor 3, the condensation mechanism 4, and the evaporative mechanism 2 are connected to one another in that order. The evaporative mechanism 2 and the compressor 3 are connected to each other with a passage 5a. The compressor 3 and the condensation mechanism 4 are connected to each other with a passage 5b. The condensation mechanism 4 and the evaporative mechanism 2 are connected to each other with a passage 5c. The main circuit 10, the condensation-side circulation circuit 20, and the evaporation-side circulation circuit 30 are filled with a refrigerant. The refrigerant is at a negative pressure, i.e., a pressure lower than the atmospheric

pressure. The saturated vapor pressure of the refrigerant at room temperature (according to JIS Z8703 of Japanese Industrial Standards, $20^{\circ}\text{C} \pm 15^{\circ}\text{C}$) is a negative pressure. The refrigerant is, for example, chiefly composed of water or alcohol. The main circuit 10 causes the refrigerant whose saturated vapor pressure at room temperature is a negative pressure to circulate there-through.

[0038] The compressor 3 compresses refrigerant vapor. The compressed refrigerant vapor flows through the passage 5b and is supplied to the condensation mechanism 4. The compressor 3 is typically an axial or centrifugal turbocompressor. In a case where the compressor 3 is a turbocompressor, if any droplets are taken into the compressor 3, the droplets may collide with an impeller and damage the impeller.

[0039] The condensation mechanism 4 condenses the refrigerant vapor and stores the resulting refrigerant liquid. The refrigerant liquid obtained through the condensation by the condensation mechanism 4 is supplied to the evaporative mechanism 2 through the passage 5c. The evaporative mechanism 2 stores the refrigerant liquid and evaporates the refrigerant liquid. The refrigerant vapor obtained through the evaporation by the evaporative mechanism 2 is supplied to the compressor 3 through the passage 5a.

[0040] The condensation-side circulation circuit 20 includes a pump 6 and a heat exchanger for heat dissipation 7. A portion of the refrigerant liquid that has been stored in the condensation mechanism 4 is supplied to the heat exchanger for heat dissipation 7 by the pump 6. The condensation mechanism 4 includes, for example, a heat-insulating, pressure-resistant, hollow container. The heat exchanger for heat dissipation 7 is, for example, a fin tube type heat exchanger that allows the refrigerant liquid and outdoor air to exchange heat with each other. In the heat exchanger for heat dissipation 7, the refrigerant liquid exchanges heat with, for example, outdoor air, whereby the refrigerant liquid dissipates heat. The refrigerant liquid that has dissipated heat in the heat exchanger for heat dissipation 7 returns into the condensation mechanism 4. The refrigerant vapor that has been compressed by the compressor 3 is supplied to the condensation mechanism 4 through the passage 5b. The refrigerant liquid that has returned from the condensation-side circulation circuit 20 to the condensation mechanism 4 cools and thus condenses the refrigerant vapor that has been supplied to the condensation mechanism 4 through the passage 5b. The refrigerant liquid obtained through the condensation of the refrigerant vapor and whose temperature has been raised is supplied to the heat exchanger for heat dissipation 7 by the pump 6 and dissipates heat in the heat exchanger for heat dissipation 7 again. A portion of the refrigerant liquid that has been stored in the condensation mechanism 4 is supplied to the evaporative mechanism 2 through the passage 5c.

[0041] The evaporation-side circulation circuit 30 includes a pump 8, a heat exchanger for heat absorption

9, and a decompression mechanism 12. The evaporation-side circulation circuit 30 is configured such that the refrigerant liquid that has been stored in the evaporative mechanism 2 is supplied to the heat exchanger for heat absorption 9. The evaporation-side circulation circuit 30 is configured such that the refrigerant having absorbed heat in the heat exchanger for heat absorption 9 and thus having a pressure higher than the pressure in the evaporative mechanism 2 undergoes pressure reduction in the decompression mechanism 12 and then returns to the evaporative mechanism 2. Specifically, the evaporative mechanism 2 and the pump 8 are connected to each other with a passage 30a. The pump 8 and the heat exchanger for heat absorption 9 are connected to each other with a passage 30b. The heat exchanger for heat absorption 9 and the evaporative mechanism 2 are connected to each other with a passage 30c. The decompression mechanism 12 is provided in the passage 30c. The decompression mechanism 12 is, for example, a valve, a nozzle, or a capillary tube. The valve employed as the decompression mechanism 12 is, for example, a motor valve whose opening degree is adjustable. The nozzle employed as the decompression mechanism 12 is, for example, a throttle nozzle. The decompression mechanism 12 may be a tube such as a capillary tube.

[0042] The refrigerant liquid whose temperature has been dropped through the evaporation in the evaporative mechanism 2 and that has been stored in the evaporative mechanism 2 is supplied to the heat exchanger for heat absorption 9 by the pump 8. The evaporative mechanism 2 includes, for example, a heat-insulating, pressure-resistant, hollow container. The heat exchanger for heat absorption 9 is, for example, a fin tube type heat exchanger that allows the refrigerant liquid and indoor air to exchange heat with each other. The refrigerant liquid that has been supplied to the heat exchanger for heat absorption 9 exchanges heat with the indoor air and thus absorbs heat from the indoor air. That is, the refrigeration-cycle equipment 1 serves as an air conditioner that cools an indoor space. The pressure of the refrigerant liquid that has been supplied to the heat exchanger for heat absorption 9 is increased by the pump 8 and is therefore higher than that in the evaporative mechanism 2. The refrigerant liquid that has flowed through the heat exchanger for heat absorption 9 undergoes pressure reduction in the decompression mechanism 12. The refrigerant whose pressure has been reduced returns to the evaporative mechanism 2 with, depending on situations, refrigerant liquid droplets.

[0043] As illustrated in Fig. 2A, the refrigeration-cycle equipment 1 includes an interaction mechanism 35 that prevents the droplets contained in the refrigerant that has returned from the evaporation-side circulation circuit 30 to the evaporative mechanism 2 from being fed into the compressor 3. The interaction mechanism 35 corresponds to a connection portion 34a for the evaporation-side circulation circuit 30. The connection portion 34a is connected to the evaporative mechanism 2 such that the

refrigerant that has absorbed heat in the heat exchanger for heat absorption 9 returns into the refrigerant liquid stored in the evaporative mechanism 2. A return port 36 that allows the refrigerant to return to the evaporative mechanism 2 is provided at the connection portion 34a. Specifically, the return port 36 is provided below the surface of the refrigerant liquid stored in the evaporative mechanism 2 and in an internal space of the evaporative mechanism 2. As illustrated in Fig. 2B, an end of the connection portion 34a may project into the internal space of the evaporative mechanism 2. In that case, the return port 36 is provided below the surface of the refrigerant liquid stored in the evaporative mechanism 2 and in the internal space of the evaporative mechanism 2. That is, the connection portion 34a extends through the wall of the evaporative mechanism 2 up to a position in the internal space of the evaporative mechanism 2, with the end of the connection portion 34a being positioned below the surface of the refrigerant liquid stored in the evaporative mechanism 2. Such a configuration reduces the probability that bubbles that have been generated by the refrigerant vapor contained in the refrigerant flowing through the connection portion 34a and have returned into the evaporative mechanism 2 may be supplied into the evaporation-side circulation circuit 30. Accordingly, the probability that the refrigerant flowing through the heat exchanger for heat absorption 9 may contain bubbles is reduced. Therefore, the heat exchanging efficiency of the heat exchanger for heat absorption 9 and the efficiency (coefficient of performance, abbreviated to COP) of the refrigeration-cycle equipment 1 are increased. Such knowledge comes from findings made by the present inventors that the efficiency of the refrigeration-cycle equipment 1 configured to allow the refrigerant having absorbed heat in the heat exchanger for heat absorption 9 to return into the refrigerant liquid stored in the evaporative mechanism 2 is lower than the efficiency of refrigeration-cycle equipment configured to allow a refrigerant having absorbed heat in a heat exchanger for heat absorption to return to a position above the surface of a refrigerant liquid stored in an evaporative mechanism. This knowledge is novel and is not found in the known art.

[0044] The internal space of the evaporative mechanism 2 has, for example, a column shape. In the present embodiment, the internal space of the evaporative mechanism 2 has a circular column shape. The top and the bottom of the internal space of the evaporative mechanism 2 may each be formed of a dome-shaped wall. The connection portion 34a is connected to the bottom face of the container included in the evaporative mechanism 2. The connection portion 34a forms a portion of the passage 30c. A pipe 32 that forms the passage 30a is connected to the bottom face of the evaporative mechanism 2. Since the pipe 32 is connected to the evaporative mechanism 2, an outlet 33 for supplying the refrigerant liquid stored in the evaporative mechanism 2 to the evaporation-side circulation circuit 30 is provided. Further-

more, a pipe 50 that forms the passage 5c is connected to the side face of the evaporative mechanism 2 and at a position near the bottom face. A pipe 70 that forms the passage 5a is connected to a wall surface of the evaporative mechanism 2 and at a position above the surface of the refrigerant liquid stored in the evaporative mechanism 2. In the present embodiment, the pipe 70 is connected to the top face of the evaporative mechanism 2. The pipe 70 may alternatively be connected to the side face of the evaporative mechanism 2. For example, in a plan view of one of the openings of the passage 5a that is on the side of the evaporative mechanism 2 and the return port 36, the opening of the passage 5a on the side of the evaporative mechanism 2 is positioned across the central axis of the internal space of the evaporative mechanism 2 from the return port 36.

[0045] The connection portion 34a is connected to the bottom face of the evaporative mechanism 2. Hence, the refrigerant that has absorbed heat in the heat exchanger for heat absorption 9 returns into the refrigerant liquid stored in the evaporative mechanism 2. If the refrigerant flowing in the connection portion 34a contains any droplets, the droplets are taken into the refrigerant liquid in the evaporative mechanism 2 because the refrigerant returning to the evaporative mechanism 2 through the connection portion 34a comes into contact with the refrigerant liquid stored in the evaporative mechanism 2. Therefore, refrigerant liquid droplets are prevented from being taken into the compressor 3 through the passage 5a. If the refrigerant flowing in the connection portion 34a contains refrigerant vapor, the refrigerant vapor flows through the refrigerant liquid stored in the evaporative mechanism 2 and is taken into the compressor 3 through the passage 5a. The connection portion 34a is connected to the evaporative mechanism 2 orthogonally to the bottom inner surface of the evaporative mechanism 2. The connection portion 34a may alternatively be connected to the evaporative mechanism 2 in such a manner as to be tilted with respect to the bottom inner surface of the evaporative mechanism 2. As another alternative, the connection portion 34a may be connected to the side face of the evaporative mechanism 2. In that case, the connection portion 34a may be orthogonal to or tilted with respect to the side inner surface of the evaporative mechanism 2.

[0046] The distance between the surface of the refrigerant liquid stored in the evaporative mechanism 2 and the return port 36 is desirably determined such that the momentum of the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a is satisfactorily reduced at the surface of the refrigerant liquid stored in the evaporative mechanism 2.

[0047] The distance between the outlet 33 and the return port 36 is, for example, 10 mm or larger. In such a configuration, the refrigerant vapor contained in the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a does not tend to flow out of the evaporative mechanism 2 through the out-

let 33. Hence, the refrigerant vapor is prevented from flowing into the pump 8, and the capability of the pump 8 to supply the refrigerant liquid is assuredly exerted.

[0048] The refrigeration-cycle equipment 1 may be configured as, for example, an air conditioner that is capable of switching its operation between an air-cooling operation and an air-heating operation by connecting an outdoor heat exchanger and an indoor heat exchanger to the evaporative mechanism 2 and to the condensation mechanism 4 with a four-way valve. When the refrigeration-cycle equipment 1 performs an air-cooling operation, the outdoor heat exchanger functions as the heat exchanger for heat dissipation 7, while the indoor heat exchanger functions as the heat exchanger for heat absorption 9. When the refrigeration-cycle equipment 1 performs an air-heating operation, the outdoor heat exchanger functions as the heat exchanger for heat absorption 9, while the indoor heat exchanger functions as the heat exchanger for heat dissipation 7. The refrigeration-cycle equipment 1 is not necessarily configured as an air conditioner and may be, for example, a chiller. In the heat exchanger for heat dissipation 7 and in the heat exchanger for heat absorption 9, the refrigerant may exchange heat with either a gas other than air or a liquid. The specifications of the heat exchanger for heat dissipation 7 and the heat exchanger for heat absorption 9 are not particularly limited, as long as the heat exchanger for heat dissipation 7 and the heat exchanger for heat absorption 9 are each of an indirect type.

Modified Examples

[0049] The above embodiment can be modified from various viewpoints. Now, modified examples of the above embodiment will be described. Configurations according to the following modified examples are the same as the configuration according to the above embodiment, unless particularly specified. Elements the same as or like those described in the above embodiment are denoted by corresponding ones of the reference numerals that are used in the above embodiment, and description of such elements may be omitted. In the following modified examples, the same or like elements are denoted by the same reference numerals, and redundant description of such elements may be omitted.

First Modified Example

[0050] As illustrated in Fig. 3, the interaction mechanism 35 may be, for example, a connection portion 34b that is connected to the side face of the evaporative mechanism 2. The connection portion 34b is connected to the evaporative mechanism 2 such that the flow of the refrigerant that has returned from the evaporation-side circulation circuit 30 to the evaporative mechanism 2 has a velocity component in a spiral circumferential direction of the internal space. Specifically, the connection portion 34b is connected to the evaporative mechanism 2 such

that the central axis of a passage provided by the connection portion 34b does not intersect the central axis of the internal space of the evaporative mechanism 2. Thus, as illustrated in Fig. 4, the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34b swirls in the spiral circumferential direction of the internal space of the evaporative mechanism 2. Therefore, if the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34b contains refrigerant liquid droplets, the droplets tend to gather on the outer circumferential side of the internal space of the evaporative mechanism 2 under a centrifugal force, whereas the refrigerant vapor tends to gather around the central axis of the internal space of the evaporative mechanism 2. Consequently, the refrigerant liquid droplets are prevented from being fed into the compressor 3. In Figs. 3 and 4, the negative side in the z-axis direction corresponds to the vertical direction, and the x-y plane corresponds to a plane that is orthogonal to the z axis.

[0051] As long as the flow of the refrigerant that has returned from the evaporation-side circulation circuit 30 to the evaporative mechanism 2 has the velocity component in the spiral circumferential direction of the internal space of the evaporative mechanism 2, the connection portion 34b may be connected to the bottom face of the evaporative mechanism 2. In such a configuration, the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34b can be made to swirl in the spiral circumferential direction of the internal space or to undergo a helical motion. Thus, the refrigerant that has returned to the evaporative mechanism 2 can be kept for a long time in the refrigerant liquid stored in the evaporative mechanism 2. Accordingly, if the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34b contains refrigerant liquid droplets, the refrigerant liquid droplets are prevented from being separated from the refrigerant and being fed into the compressor 3.

Second Modified Example

[0052] As illustrated in Fig. 5A, the refrigeration-cycle equipment 1 may further include a discharge preventing wall 37 provided above the connection portion 34a. In such a configuration, the connection portion 34a is connected to the evaporative mechanism 2 such that the refrigerant flows into the evaporative mechanism 2 in an upward or obliquely upward direction. The discharge preventing wall 37 prevents the flow of the refrigerant that has returned from the evaporation-side circulation circuit 30 to the evaporative mechanism 2 from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism 2. Specifically, the discharge preventing wall 37 is provided in the evaporative mechanism 2 and below the surface of the refrigerant liquid stored in the evaporative mechanism 2. The flow of the refrigerant that has returned to the evaporative

mechanism 2 through the connection portion 34a is decelerated by colliding with the discharge preventing wall 37. Thus, the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a is prevented from being discharged from the surface of the refrigerant liquid. Even if the distance between the surface of the refrigerant liquid stored in the evaporative mechanism 2 and the return port 36 is short, the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a can be prevented from being discharged. Therefore, the size of the evaporative mechanism 2 can be reduced.

[0053] The discharge preventing wall 37 is, for example, at 90° with respect to the flow of the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a. However, the angle of the discharge preventing wall 37 is not particularly limited, as long as the flow of the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a collides with the discharge preventing wall 37. The discharge preventing wall 37 may have a flat or curved surface, or may have a plurality of through holes. Alternatively, a plurality of discharge preventing walls 37 may be provided. As long as the flow of the refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a collides with the discharge preventing wall 37, the number of discharge preventing walls 37 and the shape of the discharge preventing wall 37 are not particularly limited. In a plan view of the discharge preventing wall 37 and the return port 36, for example, the entirety of the return port 36 is covered by the discharge preventing wall 37. Thus, the above advantageous effect is more assuredly produced. For example, when the axial line of the connection portion 34a is extended into the internal space of the evaporative mechanism 2, the discharge preventing wall 37 is positioned on the extension of the axial line. Thus, the above advantageous effect is more assuredly produced. As illustrated in Fig. 5B, the connection portion 34a may extend through the wall of the evaporative mechanism 2 up to a position in the internal space of the evaporative mechanism 2 and below the discharge preventing wall 37.

[0054] As illustrated in Fig. 5C, the discharge preventing wall 37 may have a hemispherical shape with a plurality of through holes 37h (orifices). In such a case, the discharge preventing wall 37 is provided above the connection portion 34a in such a manner as to cover the return port 36 in the internal space of the evaporative mechanism 2. The plurality of through holes 37h are distributed over substantially the entirety of the discharge preventing wall 37. The plurality of through holes 37h include, for example, a plurality of groups of through holes, each group including a plurality of through holes that are arranged annularly at a specific height. The sum of the opening areas of the respective through holes 37h is larger than the cross sectional area of the passage provided by the connection portion 34a. The flow of the

refrigerant that has returned to the evaporative mechanism 2 through the connection portion 34a collides with the discharge preventing wall 37 and is thus decelerated. Consequently, the flow of the refrigerant having returned to the evaporative mechanism 2 from the evaporation-side circulation circuit 30 is prevented from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism 2. Furthermore, since the refrigerant flows through the plurality of through holes 37h, the flow of the refrigerant is distributed radially as illustrated in Fig. 5C.

Third Modified Example

[0055] As illustrated in Fig. 6, the refrigeration-cycle equipment 1 may further include a partition wall 39 provided in the evaporative mechanism 2 and between the outlet 33 and the return port 36. For example, the partition wall 39 is positioned on a line connecting the outlet 33 and the return port 36 by the shortest distance. The partition wall 39 prevents the refrigerant vapor contained in the refrigerant having returned to the evaporative mechanism 2 through the return port 36 from flowing out of the evaporative mechanism 2 through the outlet 33. Preventing the refrigerant vapor from flowing out of the evaporative mechanism 2 through the outlet 33 by using the partition wall 39 is particularly advantageous in a case where, for example, the outlet 33 and the return port 36 are not at a sufficient distance from each other. Hence, the size of the evaporative mechanism 2 can be reduced.

[0056] The partition wall 39 is, for example, provided on the bottom surface of the evaporative mechanism 2 and is at 90° with respect to the surface of the refrigerant liquid stored in the evaporative mechanism 2. However, the orientation and the position of the partition wall 39 are not particularly limited, as long as the partition wall 39 prevents the refrigerant vapor contained in the refrigerant having returned to the evaporative mechanism 2 from flowing out of the evaporative mechanism 2 through the outlet 33. The partition wall 39 may have a flat or curved surface. Alternatively, a plurality of partition walls 39 may be provided. That is, as long as the refrigerant vapor contained in the refrigerant having returned to the evaporative mechanism 2 through the return port 36 is prevented from flowing out of the evaporative mechanism 2 through the outlet 33, the shape of the partition wall 39 and the number of partition walls 39 are not particularly limited. Moreover, the partition wall 39 may have a mesh structure. Such a mesh structure can catch refrigerant liquid droplets.

Fourth Modified Example

[0057] As illustrated in Fig. 7, the connection portion 34a may extend through the wall of the evaporative mechanism 2 into the internal space of the evaporative mechanism 2 but not beyond the surface of the refrigerant liquid stored in the evaporative mechanism 2. In such a

configuration, the connection portion 34a includes a discharge preventing mechanism 38 that prevents the flow of the refrigerant having returned from the evaporation-side circulation circuit 30 to the evaporative mechanism 2 from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism 2. Since the connection portion 34a includes the discharge preventing mechanism 38, the flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34a is prevented from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism 2. Thus, refrigerant liquid droplets generated by the disturbance of the surface of the refrigerant liquid stored in the evaporative mechanism 2 are prevented from being fed into the compressor 3. The connection portion 34a extends, for example, through the wall of the evaporative mechanism 2 up to a position in the internal space of the evaporative mechanism 2 and below the surface of the refrigerant liquid stored in the evaporative mechanism 2. The connection portion 34a extends vertically upward.

[0058] The discharge preventing mechanism 38 includes, for example, a widened portion 34g. The widened portion 34g forms a passage that is positioned above the bottom of the evaporative mechanism 2 and whose cross sectional area increases in the direction of the flow of the refrigerant in the connection portion 34a. Since the speed of the refrigerant flowing through the connection portion 34a is reduced in the passage provided by the widened portion 34g, the flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34a is prevented from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism 2. Thus, refrigerant liquid droplets generated by the disturbance of the surface of the refrigerant liquid stored in the evaporative mechanism 2 are prevented from being fed into the compressor 3.

[0059] As illustrated in Fig. 8, the widened portion 34g may have a stepped shape in cross sectional view taken along the central axis of the connection portion 34a. The widened portion 34g having such a shape can be manufactured by, for example, welding a plurality of pipes having different inside diameters that conform to Japanese Industrial Standards (JIS). The widened portion 34g only needs to be shaped such that the cross sectional area of the passage provided by the widened portion 34g at the downstream end is larger than the cross sectional area of the passage provided by the widened portion 34g at the upstream end. Alternatively, for example, part of the widened portion 34g may be contracted. As illustrated in Fig. 9, the pipe 32 that forms the passage 30a may be connected to the sidewall of the evaporative mechanism 2 and below the surface of the refrigerant liquid stored in the evaporative mechanism 2.

[0060] As illustrated in Fig. 10, the connection portion 34a may further include an extended portion 34h. The extended portion 34h extends upward from the widened portion 34g and forms a passage whose cross sectional

area is constant in the direction of the flow of the refrigerant in the connection portion 34a. In this passage, the sizes of bubbles generated by the refrigerant vapor contained in the refrigerant flowing through the connection portion 34a are adjusted. Hence, such bubbles are prevented from being supplied to the evaporation-side circulation circuit 30 after returning to the evaporative mechanism 2. Thus, the refrigerant vapor is prevented from flowing into the pump 8, and the capability of the pump 8 to supply the refrigerant liquid is assuredly exerted. In such a case, the refrigeration-cycle equipment 1 may be configured as illustrated in Fig. 11.

[0061] The refrigeration-cycle equipment 1 illustrated in Fig. 11 further includes a heat-absorption-side temperature sensor 16, a refrigerant vapor temperature sensor 17, a liquid level sensor 18, and a control unit 15, and has the same configuration as the refrigeration-cycle equipment 1 according to the present embodiment, except that the connection portion 34a is configured as illustrated in Fig. 10. The decompression mechanism 12 is a valve. The decompression mechanism 12 is, for example, a motor valve whose opening degree is adjustable. The heat-absorption-side temperature sensor 16 detects the temperature of the refrigerant returning to the evaporative mechanism 2 after absorbing heat in the heat exchanger for heat absorption 9. The heat-absorption-side temperature sensor 16 is attached to, for example, a pipe included in the evaporation-side circulation circuit 30 and at a position on the downstream side with respect to the heat exchanger for heat absorption 9 in the direction of the flow of the refrigerant. The refrigerant vapor temperature sensor 17 detects the temperature of the refrigerant vapor in the evaporative mechanism 2. The refrigerant vapor temperature sensor 17 is attached to, for example, a wall surface of the evaporative mechanism 2 and above the surface of the refrigerant liquid stored in the evaporative mechanism 2. The liquid level sensor 18 detects the level of the refrigerant liquid stored in the evaporative mechanism 2. The liquid level sensor 18 is of, for example, a float type, an optical type, an ultrasonic wave type, or a capacitance type. The control unit 15 controls the level of the refrigerant liquid stored in the evaporative mechanism 2 by adjusting the opening degree of the valve as the decompression mechanism 12 on the basis of the values detected by the heat-absorption-side temperature sensor 16, the refrigerant vapor temperature sensor 17, and the liquid level sensor 18. Therefore, as illustrated in Fig. 11, the control unit 15 is connected to the heat-absorption-side temperature sensor 16, the refrigerant vapor temperature sensor 17, and the liquid level sensor 18 so as to receive the values detected by the heat-absorption-side temperature sensor 16, the refrigerant vapor temperature sensor 17, and the liquid level sensor 18. The control unit 15 is also connected to the decompression mechanism 12 so as to transmit to the decompression mechanism 12 a signal for adjusting the opening degree of the valve as the decompression mechanism 12. The connections between

the control unit 15 and the heat-absorption-side temperature sensor 16, the refrigerant vapor temperature sensor 17, the liquid level sensor 18, and the decompression mechanism 12 may be either wire connection or radio connection.

[0062] The control unit 15 controls the level of the refrigerant liquid stored in the evaporative mechanism 2 such that, for example, the refrigerant in the connection portion 34a flows in a single phase (in a liquid phase) up to the upper end of the widened portion 34g. That is, the control unit 15 controls the level of the refrigerant liquid stored in the evaporative mechanism 2 such that bubbles of the refrigerant vapor are generated above the upper end of the widened portion 34g. The control unit 15 acquires the values detected by the heat-absorption-side temperature sensor 16, the refrigerant vapor temperature sensor 17, and the liquid level sensor 18. The control unit 15 calculates, from the value detected by the heat-absorption-side temperature sensor 16, the saturated vapor pressure P_h [Pa] of the refrigerant that is at the temperature detected by the heat-absorption-side temperature sensor 16. The control unit 15 also calculates, from the value detected by the refrigerant vapor temperature sensor 17, the saturated vapor pressure P_s [Pa] of the refrigerant that is at the temperature detected by the refrigerant vapor temperature sensor 17. Here, the density and the gravitational acceleration of the refrigerant liquid stored in the evaporative mechanism 2 are denoted as ρ [kg/m³] and g [m/s²], respectively; and the height from the upper end of the widened portion 34g to the surface of the refrigerant liquid stored in the evaporative mechanism 2 is denoted as h [m]. To allow the refrigerant in the connection portion 34a to flow in a single phase (in a liquid phase) up to the upper end of the widened portion 34g, a relationship of $P_h - P_s \leq \rho gh$ needs to be satisfied. The control unit 15 controls the level of the refrigerant liquid stored in the evaporative mechanism 2 by adjusting the opening degree of the valve as the decompression mechanism 12 so that the above relationship is satisfied.

[0063] As illustrated in Fig. 12, the discharge preventing mechanism 38 may further include a flow distributing plates 34i, in addition to the widened portion 34g. The flow distributing plates 34i are provided such that the central axis of the connection portion 34a passes there-through. The flow distributing plates 34i each have a plurality of through holes 34j. The flow distributing plates 34i reduce the spatial variation in the speed of the refrigerant flowing through the connection portion 34a and returning to the evaporative mechanism 2. The outer circumferential edges of the respective flow distributing plates 34i are connected to the inner circumferential surface of the widened portion 34g. The sum of the opening areas of the respective through holes 34j is larger than the cross sectional area of the passage provided by the connection portion 34a and positioned on the upstream side with respect to the widened portion 34g in the direction of the flow of the refrigerant in the connection portion 34a. Therefore, the speed of the refrigerant flowing through

the plurality of through holes 34j is prevented from becoming too high. The number of flow distributing plates 34i arranged in the direction of the flow of the refrigerant in the connection portion 34a may be one or two or more.

[0064] As illustrated in Fig. 13, the discharge preventing mechanism 38 may further include a porous member 34k, in addition to the widened portion 34g. The porous member 34k is provided such that the central axis of the connection portion 34a passes therethrough. Thus, the widened portion 34g and the porous member 34k decelerate the flow of the refrigerant returning from the connection portion 34a to the evaporative mechanism 2 and reduce the spatial variation in the flow speed of the refrigerant. Moreover, the widened portion 34g and the porous member 34k cause bubbles contained in the refrigerant to be broken at the surface of the refrigerant liquid, thereby preventing the occurrence of pressure variation in the evaporative mechanism 2. That is, in the discharge preventing mechanism 38 illustrated in Fig. 12, bubbles contained in the refrigerant are trapped by the flow distributing plates 34i. Consequently, bubbles of larger sizes may be generated. If such bubbles go upward and are broken at the liquid surface, the pressure in the evaporative mechanism 2 may vary. To avoid such a situation, in the discharge preventing mechanism 38 illustrated in Fig. 13, the outer circumferential edge of the porous member 34k is connected to the inner circumferential surface of the widened portion 34g. Therefore, the sizes of bubbles contained in the refrigerant are reduced while the bubbles pass through the porous member 34k. Thus, the probability that bubbles of larger sizes may be generated and pressure variation may occur in the evaporative mechanism 2 is reduced. The porous member 34k is made of, for example, urethane foam, a metal-based porous material, or melamine-resin sponge. The porous member 34k may alternatively be a platelike member having a plurality of holes, such as a punched metal plate.

[0065] As illustrated in Fig. 14, the discharge preventing mechanism 38 may further include a narrowed portion 34m, in addition to the widened portion 34g. The narrowed portion 34m projects in such a manner as to be narrowed in a direction opposite to the direction of the flow of the refrigerant in the connection portion 34a. The narrowed portion 34m has a tip positioned on the central axis of the connection portion 34a. Thus, the flow of the refrigerant is evenly distributed by the narrowed portion 34m. Moreover, while the refrigerant is flowing, the occurrence of flow separation (the generation of vortices) is suppressed. Therefore, the pressure loss in the flow of the refrigerant is small.

Fifth Modified Example

[0066] As illustrated in Fig. 15, the evaporative mechanism 2 may have an internal space that is narrowed toward the bottom of the evaporative mechanism 2. In such a case, the connection portion 34a is connected to the bottom of the evaporative mechanism 2. The con-

nection portion 34a extends vertically upward. The flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34a is decelerated in the internal space of the evaporative mechanism 2. Therefore, the flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34a is prevented from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism 2.

[0067] In such a configuration, as illustrated in Fig. 16, the refrigeration-cycle equipment 1 may further include flow distributing plates 31g. The flow distributing plates 31g are provided in the internal space of the evaporative mechanism 2 such that the central axis of the connection portion 34a passes therethrough. The flow distributing plates 31g each have a plurality of through holes 31h. The sum of the opening areas of the respective through holes 31h is larger than the cross sectional area of the passage provided by the connection portion 34a. Hence, in the internal space of the evaporative mechanism 2, the flow distributing plates 31g reduce the spatial variation in the speed of the flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34a. Moreover, since the sum of the opening areas of the respective through holes 31h is larger than the cross sectional area of the passage provided by the connection portion 34a, the speed of the flow of the refrigerant passing through the through holes 31h is prevented from becoming too high. The number of flow distributing plates 31g arranged in the direction of the flow in the connection portion 34a may be one or two or more.

[0068] As illustrated in Fig. 17, the refrigeration-cycle equipment 1 may further include a narrowed portion 31i. The narrowed portion 31i projects in the internal space of the evaporative mechanism 2 in such a manner as to be narrowed toward the bottom of the evaporative mechanism 2. The narrowed portion 31i has a tip positioned on the central axis of the connection portion 34a. Thus, the flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34a is evenly distributed in the internal space of the evaporative mechanism 2 by the narrowed portion 31i. Moreover, while the refrigerant is flowing, the occurrence of flow separation (the generation of vortices) is suppressed. Therefore, the pressure loss in the flow of the refrigerant is small.

Sixth Modified Example

[0069] As illustrated in Fig. 18, the interaction mechanism 35 may be a connection portion 34c for the evaporation-side circulation circuit 30. The connection portion 34c is connected to the evaporative mechanism 2 such that the refrigerant returns to the evaporative mechanism 2 from a position above the surface of the refrigerant liquid stored in the evaporative mechanism 2. The connection portion 34c is connected to the evaporative mechanism 2 such that the flow of the refrigerant imme-

diately after returning to the evaporative mechanism 2 has a velocity component in the vertical direction. Specifically, the connection portion 34c extends in the vertical direction and is connected to the top face of the evaporative mechanism 2. Therefore, among velocity components of the flow of the refrigerant immediately after returning to the evaporative mechanism 2, the velocity component in the vertical direction is dominant. Hence, the flow of the refrigerant having returned to the evaporative mechanism 2 advances toward the surface of the refrigerant liquid stored in the evaporative mechanism 2. Accordingly, refrigerant liquid droplets contained in the refrigerant having returned to the evaporative mechanism 2 easily reach the surface of the refrigerant liquid stored in the evaporative mechanism 2. Consequently, the refrigerant liquid droplets are prevented from being fed into the compressor 3.

[0070] The connection portion 34c may be connected to the evaporative mechanism 2 at an obliquely downward angle as illustrated in Fig. 19, as long as the flow of the refrigerant immediately after returning to the evaporative mechanism 2 has a velocity component in the vertical direction. In such a configuration also, the flow of the refrigerant having returned to the evaporative mechanism 2 advances toward the surface of the refrigerant liquid stored in the evaporative mechanism 2. Therefore, refrigerant liquid droplets easily reach the surface of the refrigerant liquid stored in the evaporative mechanism 2. Consequently, the refrigerant liquid droplets are prevented from being fed into the compressor 3.

Seventh Modified Example

[0071] As illustrated in Fig. 20, the interaction mechanism 35 may include a connection portion 34d for the evaporation-side circulation circuit 30, and a baffle plate 40. The connection portion 34d is connected to the evaporative mechanism 2 such that the refrigerant returns to the evaporative mechanism 2 from a position above the surface of the refrigerant liquid stored in the evaporative mechanism 2. The connection portion 34d is connected to the side face of the evaporative mechanism 2. The connection portion 34d may alternatively be connected to the top face of the evaporative mechanism 2. The baffle plate 40 is a member that baffles the flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34d. The baffle plate 40 is provided in the internal space of the evaporative mechanism 2 and, for example, is attached to the top face of the evaporative mechanism 2. When the flow of the refrigerant having returned to the evaporative mechanism 2 through the connection portion 34d comes into contact with the baffle plate 40, refrigerant liquid droplets adhere to the baffle plate 40, or the direction of the flow of the refrigerant containing refrigerant liquid droplets is changed by the baffle plate 40 toward the surface of the refrigerant liquid stored in the evaporative mechanism 2. Consequently, the refrigerant liquid droplets are prevented from being

fed into the compressor 3.

[0072] As illustrated in Fig. 21, the baffle plate 40 may be provided above the return port 36 in the internal space of the evaporative mechanism 2 and on the side face of the evaporative mechanism 2. In the internal space of the evaporative mechanism 2, the baffle plate 40 only needs to be provided between the return port 36 and an opening of the evaporative mechanism 2 that corresponds to the passage 5a. Specifically, the baffle plate 40 is preferably positioned on a line connecting the return port 36 and the opening of the passage 5a on the side of the evaporative mechanism 2 by the shortest distance. The baffle plate 40 may be, for example, a plate having a flat or curved surface, a plate including a bent portion, or a plate having a meshed structure. A plurality of baffle plates 40 may be provided in the internal space of the evaporative mechanism 2. It is desirable that the baffle plate 40 extend downward in the internal space of the evaporative mechanism 2. As illustrated in Fig. 22, the baffle plate 40 may extend into the refrigerant liquid stored in the evaporative mechanism 2.

[0073] As illustrated in Fig. 23, the connection portion 34d may extend upward through the wall of the evaporative mechanism 2 up to a position above the surface of the refrigerant liquid stored in the evaporative mechanism 2. The return port 36 is positioned above the surface of the refrigerant liquid stored in the evaporative mechanism 2. The baffle plate 40 is positioned above the return port 36. In a plan view of the baffle plate 40 and the return port 36 that is seen from the side of the baffle plate 40, the entirety of the return port 36 is covered by the baffle plate 40. When the refrigerant discharged upward from the return port 36 comes into contact with the baffle plate 40, refrigerant liquid droplets adhere to the baffle plate 40, or the direction of the flow of the refrigerant containing refrigerant liquid droplets is changed by the baffle plate 40 toward the surface of the refrigerant liquid stored in the evaporative mechanism 2. Consequently, the refrigerant liquid droplets are prevented from being fed into the compressor 3.

Other Modified Examples

[0074] In the above embodiment, the refrigeration-cycle equipment 1 may include a plurality of compressors between the evaporative mechanism 2 and the condensation mechanism 4. In such a case, one of the compressors that is on the upstream side may be a turbocompressor while another on the downstream side may be a capacity compressor. The refrigeration-cycle equipment 1 may further include a cooling device that cools the refrigerant vapor having been compressed by the upstream-side compressor, the cooling device being provided in a passage that connects the upstream-side compressor and the downstream-side compressor.

[0075] The refrigeration-cycle equipment 1 may include, in the passage 5c, a decompression mechanism such as a pressure reducing valve.

[0076] The condensation mechanism 4 may be an ejector 60 illustrated in Fig. 24, instead of the hollow container illustrated in Fig. 1. The ejector 60 mixes the refrigerant vapor compressed by the compressor 3 and the refrigerant liquid together, thereby condensing the refrigerant vapor. The ejector 60 includes a first nozzle 61, a second nozzle 62, a mixing portion 63, a diffusing portion 64, a needle valve 65, and an actuator 66. The refrigerant liquid having flowed out of the heat exchanger for heat dissipation 7 into a pipe 67 is supplied as a motive fluid to the first nozzle 61. Meanwhile, the refrigerant vapor having been compressed by the compressor 3 is supplied to the second nozzle 62 from the passage 5b. Then, the refrigerant liquid is ejected from the first nozzle 61, whereby the pressure in the mixing portion 63 becomes lower than the pressure in the passage 5b. Consequently, the refrigerant vapor is continuously taken into the second nozzle 62 from the passage 5b. The refrigerant liquid ejected from the first nozzle 61 while being accelerated and the refrigerant vapor ejected from the second nozzle 62 while being expanded and accelerated are mixed together in the mixing portion 63. Then, the refrigerant vapor is condensed because of the temperature difference between the refrigerant liquid and the refrigerant vapor, the energy transfer between the refrigerant liquid and the refrigerant vapor, and a pressure increasing effect produced on the basis of the momentum transfer between the refrigerant liquid and the refrigerant vapor. The diffusing portion 64 decelerates the flow of the refrigerant, whereby the pressure recovers to a static pressure.

[0077] The flow rate of the refrigerant liquid as the motive fluid is adjustable by the needle valve 65 and the actuator 66. The cross sectional area of an orifice at the tip of the first nozzle 61 is changeable by the needle valve 65. The position of the needle valve 65 is adjustable by the actuator 66. Hence, the flow rate of the refrigerant liquid in the first nozzle 61 is adjustable.

[0078] In a case where the return port 36 is provided in the internal space of the evaporative mechanism 2 and below the surface of the refrigerant liquid stored in the evaporative mechanism 2, the refrigeration-cycle equipment 1 may further include a structure that prevents the refrigerant vapor contained in the refrigerant having returned to the evaporative mechanism 2 through the return port 36 from flowing out of the evaporative mechanism 2 from the outlet 33. Such a structure may be, for example, a meshed structure provided around the outlet 33, or a structure provided around the outlet 33 and having a plurality of through holes.

[0079] The refrigeration-cycle equipment according to the present disclosure is particularly advantageous as, for example, a home-use air conditioner or an industrial-use air conditioner. The refrigeration-cycle equipment according to the present disclosure can be used as, for example, a chiller or a heat pump.

Claims

1. Refrigeration-cycle equipment comprising:

a main circuit through which a refrigerant is circulated, saturated vapor pressure of the refrigerant at room temperature being a negative pressure, the main circuit including i) a compressor that compresses refrigerant vapor, ii) a condensation mechanism that condenses the refrigerant vapor, and iii) an evaporative mechanism that stores refrigerant liquid and that evaporates the refrigerant liquid, i) the compressor, ii) the condensation mechanism, and iii) the evaporative mechanism being connected to one another in that order;
an evaporation-side circulation circuit that includes a heat exchanger for heat absorption and includes a decompression mechanism, the refrigerant liquid stored in the evaporative mechanism being supplied to the heat exchanger for heat absorption through the evaporation-side circulation circuit, the refrigerant returning to the evaporative mechanism after the refrigerant absorbing heat in the heat exchanger for heat absorption and the pressure of the refrigerant being reduced in the decompression mechanism; and
an interaction mechanism that prevents droplets contained in the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being fed into the compressor.

2. The refrigeration-cycle equipment according to Claim 1,

wherein the interaction mechanism comprises a connection portion that is provided to the evaporative mechanism and that connects the evaporative mechanism and the evaporation-side circulation circuit, to return the refrigerant having absorbed heat in the heat exchanger for heat absorption into the refrigerant liquid stored in the evaporative mechanism, and

wherein the connection portion extends through a wall of the evaporative mechanism into an internal space of the evaporative mechanism, and an end of the connection portion is positioned below a surface of the refrigerant liquid stored in the evaporative mechanism.

3. The refrigeration-cycle equipment according to Claim 2,

wherein the internal space of the evaporative mechanism has a column shape, and
wherein a virtual line extending from the connection portion into the evaporative mechanism is off a center of the internal space having the column shape.

4. The refrigeration-cycle equipment according to Claim 2, further comprising a discharge preventing wall provided above the connection portion, the discharge preventing wall preventing a flow of the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism. 5
5. The refrigeration-cycle equipment according to Claim 2, further comprising a partition wall provided in the evaporative mechanism and between an outlet and a return port, the refrigerant liquid stored in the evaporative mechanism being supplied to the evaporation-side circulation circuit through the outlet, the return port being provided by the connection portion, and the refrigerant returning to the evaporative mechanism through the return port. 10 15
6. The refrigeration-cycle equipment according to Claim 2, wherein the connection portion includes a discharge preventing mechanism that prevents a flow of the refrigerant having returned from the evaporation-side circulation circuit to the evaporative mechanism from being discharged from the surface of the refrigerant liquid stored in the evaporative mechanism. 20 25
7. The refrigeration-cycle equipment according to Claim 6, wherein the discharge preventing mechanism includes a widened portion positioned above a bottom of the evaporative mechanism and forming a passage, cross sectional area of the passage increasing in a direction of the flow of the refrigerant in the connection portion. 30 35
8. The refrigeration-cycle equipment according to Claim 7, wherein the connection portion further includes an extended portion extending upward from the widened portion and forming a passage, cross sectional area of passage being constant in the direction of the flow of the refrigerant in the connection portion. 40
9. The refrigeration-cycle equipment according to Claim 7, wherein the discharge preventing mechanism further includes a flow distributing plate, a central axis of the connection portion passing through the flow distributing plate, the flow distributing plate having a plurality of through holes, and wherein a sum of opening areas corresponding to the respective through holes is larger than a cross sectional area of a passage that is provided by the connection portion and is positioned on an upstream side with respect to the widened portion in the direction of the flow of the refrigerant in the connection portion. 45 50 55
10. The refrigeration-cycle equipment according to Claim 7, wherein the discharge preventing mechanism further includes a porous member provided such that a central axis of the connection portion passes through the porous member. 5
11. The refrigeration-cycle equipment according to Claim 7, wherein the discharge preventing mechanism further includes a narrowed portion projecting in such a manner as to be narrowed in a direction opposite to the direction of the flow of the refrigerant in the connection portion, the narrowed portion having a tip positioned on a central axis of the connection portion. 10
12. The refrigeration-cycle equipment according to Claim 6, wherein the connection portion extends vertically upward. 15
13. The refrigeration-cycle equipment according to Claim 8, wherein the decompression mechanism is a valve, and wherein the refrigeration-cycle equipment further includes a heat-absorption-side temperature sensor that detects a temperature of the refrigerant having absorbed heat in the heat exchanger for heat absorption and returning to the evaporative mechanism; a refrigerant vapor temperature sensor that detects a temperature of the refrigerant vapor in the evaporative mechanism; a liquid level sensor that detects a level of the refrigerant liquid stored in the evaporative mechanism; and a control unit that controls the level of the refrigerant liquid stored in the evaporative mechanism by adjusting an opening degree of the valve on the basis of a value detected by the heat-absorption-side temperature sensor, a value detected by the refrigerant vapor temperature sensor, and a value detected by the liquid level sensor. 20 25 30 35 40 45 50 55
14. The refrigeration-cycle equipment according to Claim 1, wherein the interaction mechanism is a connection portion provided to the evaporative mechanism and connecting the evaporative mechanism and the evaporation-side circulation circuit to each other, the interaction mechanism allowing the refrigerant having absorbed heat in the heat exchanger for heat absorption to return into the refrigerant liquid stored in the evaporative mechanism, wherein the connection portion extends through a wall of the evaporative mechanism into an internal space of the evaporative mechanism, and an end of the connection portion is positioned above a surface of the refrigerant liquid stored in the evaporative 5

mechanism, and

wherein the end of the connection portion is oriented such that a flow of the refrigerant immediately after returning to the evaporative mechanism has a velocity component in a vertical direction.

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15. The refrigeration-cycle equipment according to Claim 1,

wherein the interaction mechanism includes

a connection portion for the evaporation-side circulation circuit, the connection portion being connected

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to the evaporative mechanism such that the refrigerant returns to the evaporative mechanism from a position above the surface of the refrigerant liquid stored in the evaporative mechanism; and

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a baffle plate that baffles a flow of the refrigerant having returned to the evaporative mechanism through the connection portion.

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FIG. 1

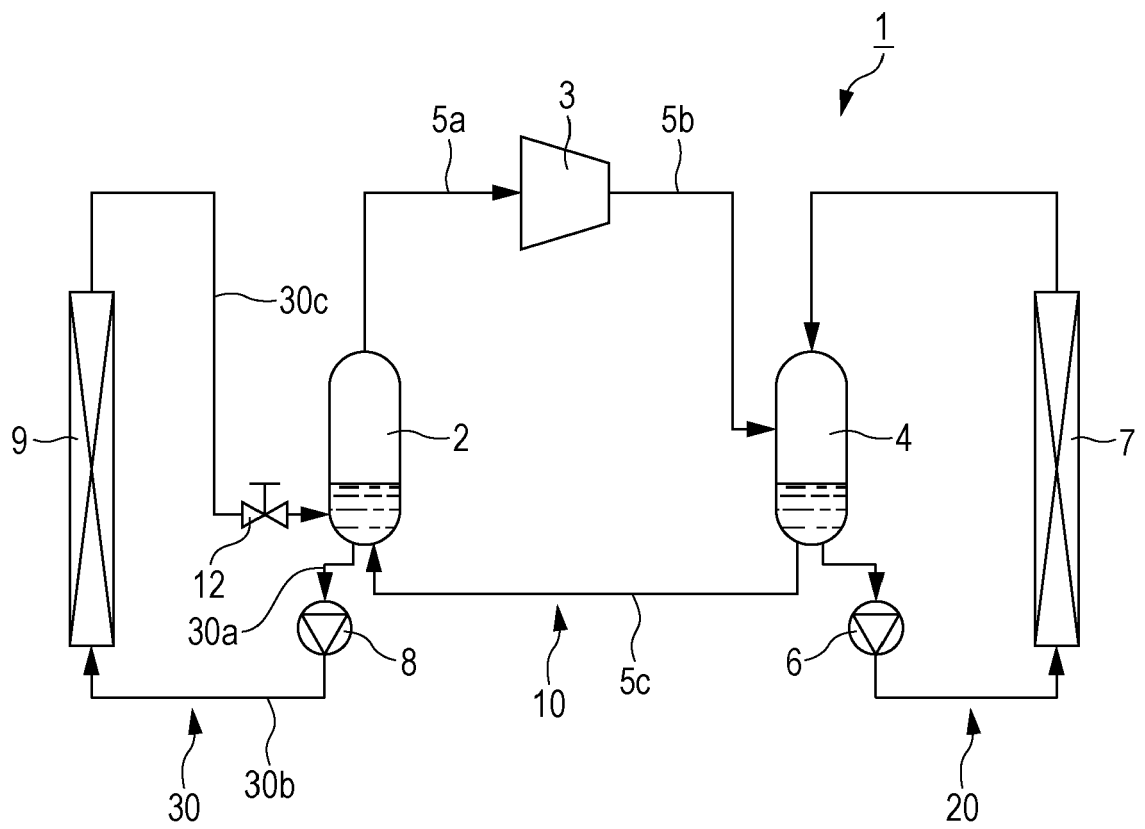


FIG. 2A

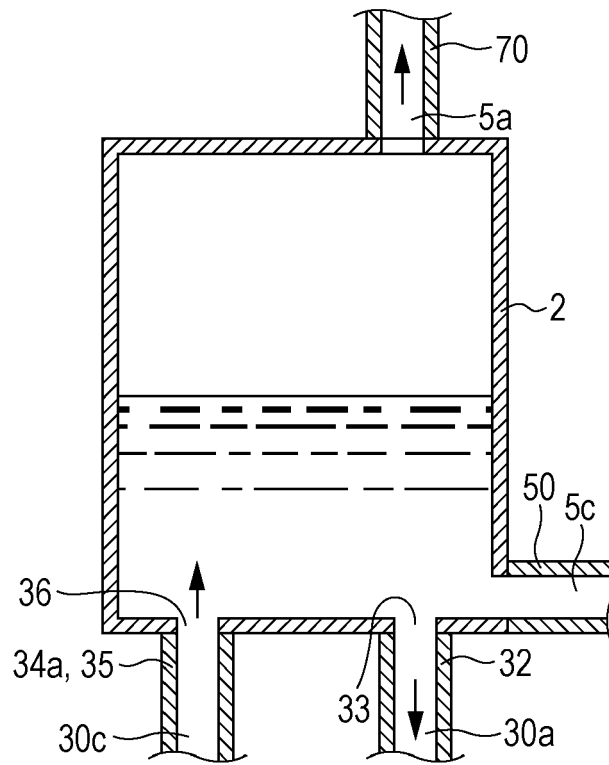


FIG. 2B

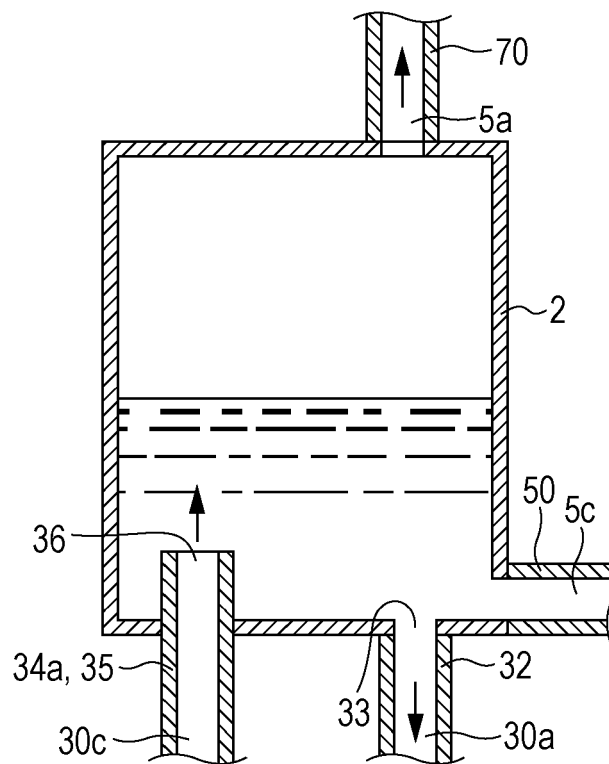


FIG. 3

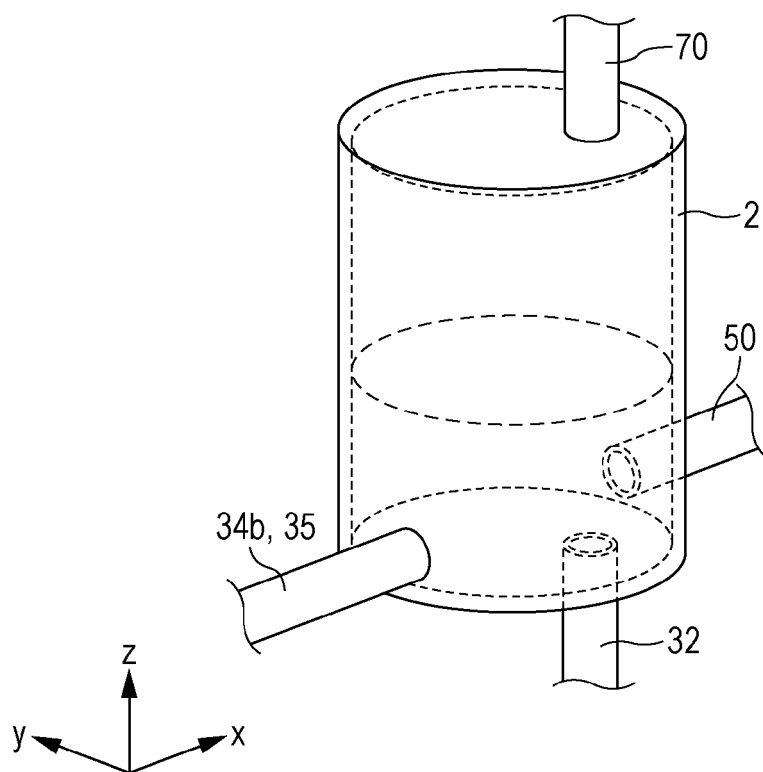


FIG. 4

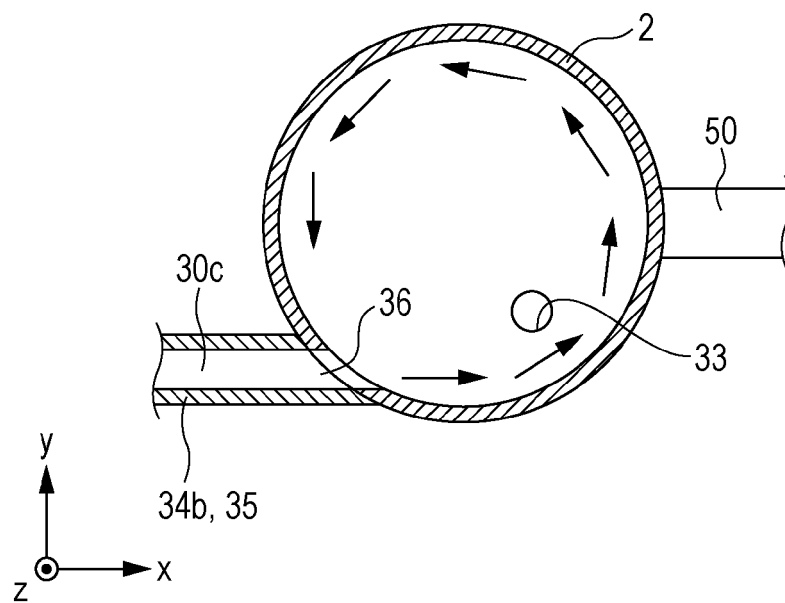


FIG. 5A

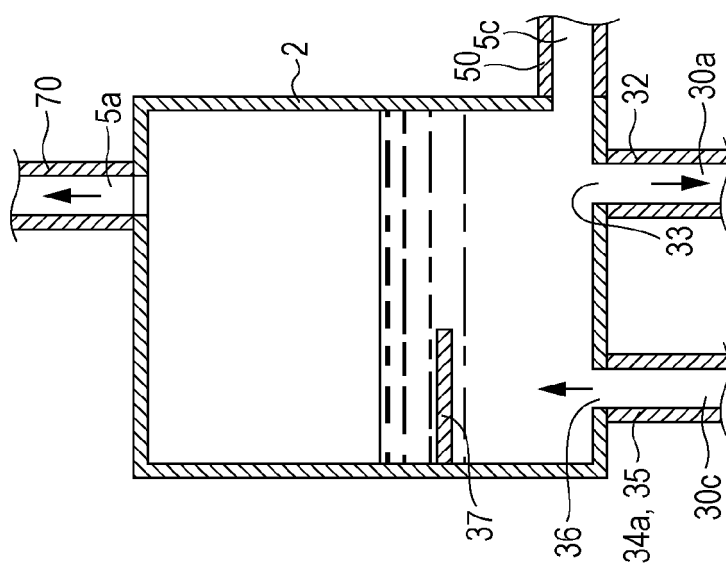


FIG. 5B

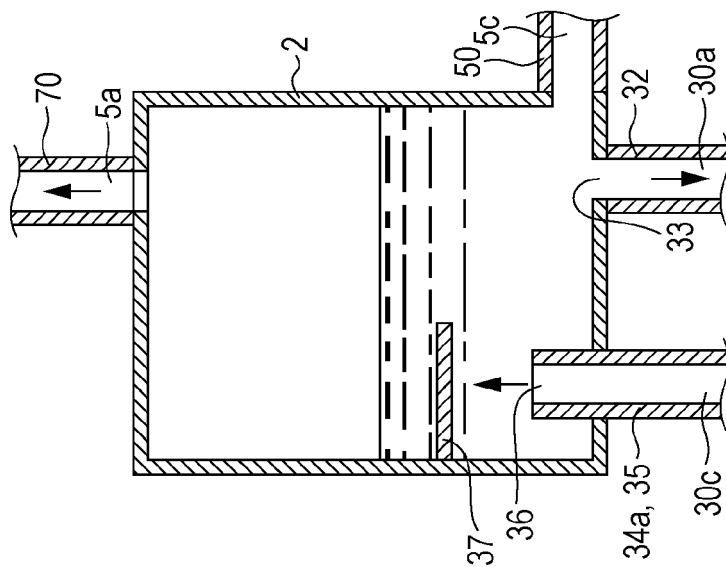


FIG. 5C

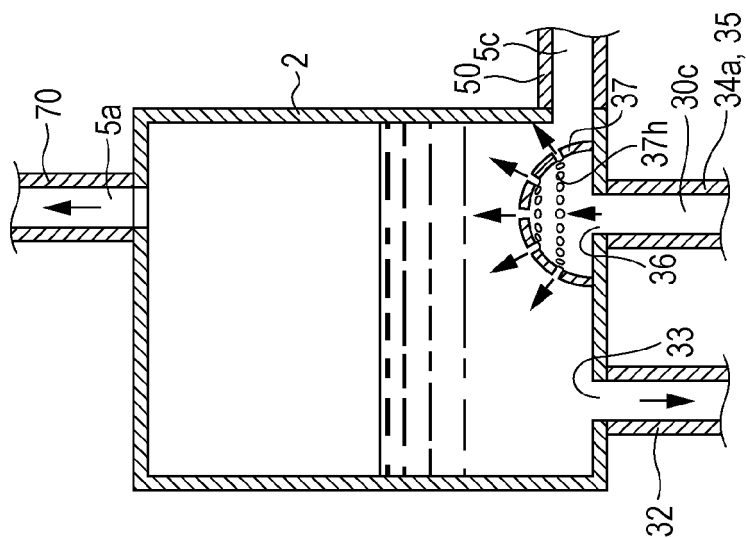


FIG. 6

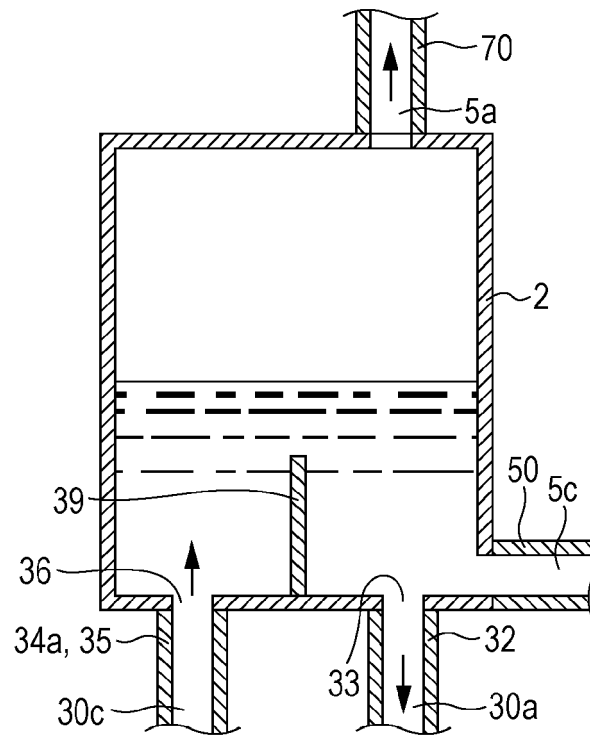


FIG. 7

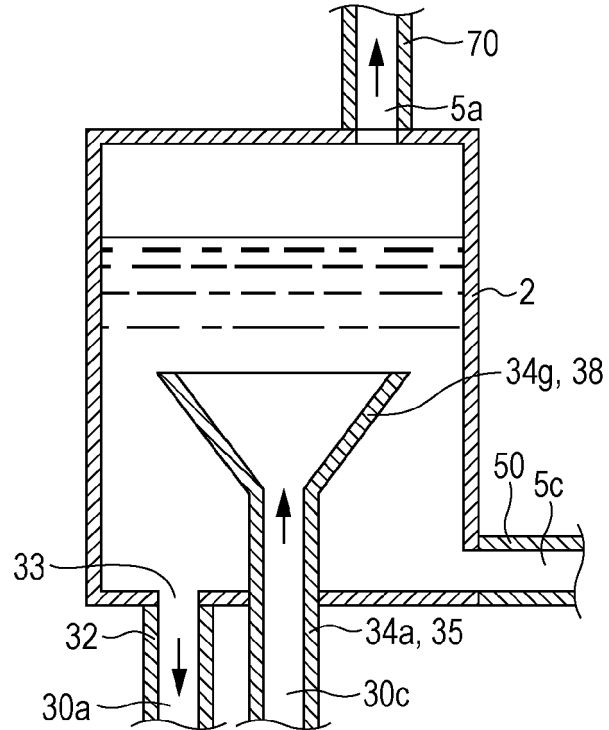


FIG. 8

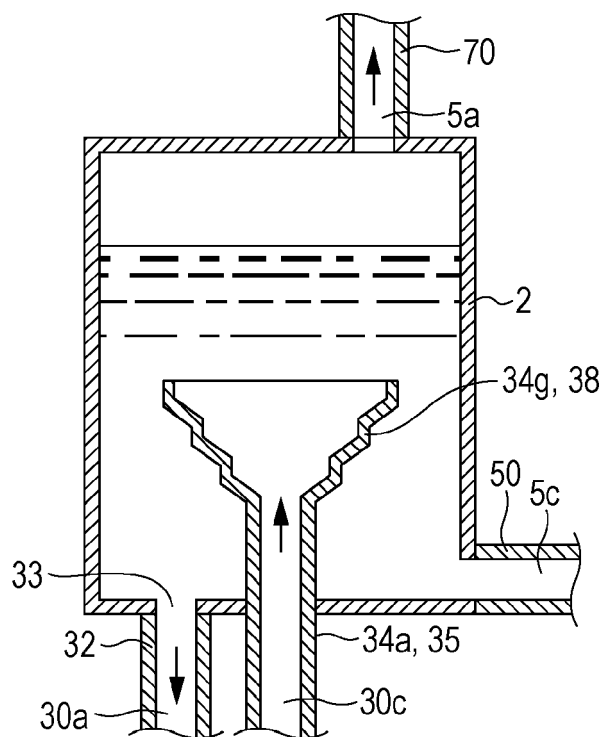


FIG. 9

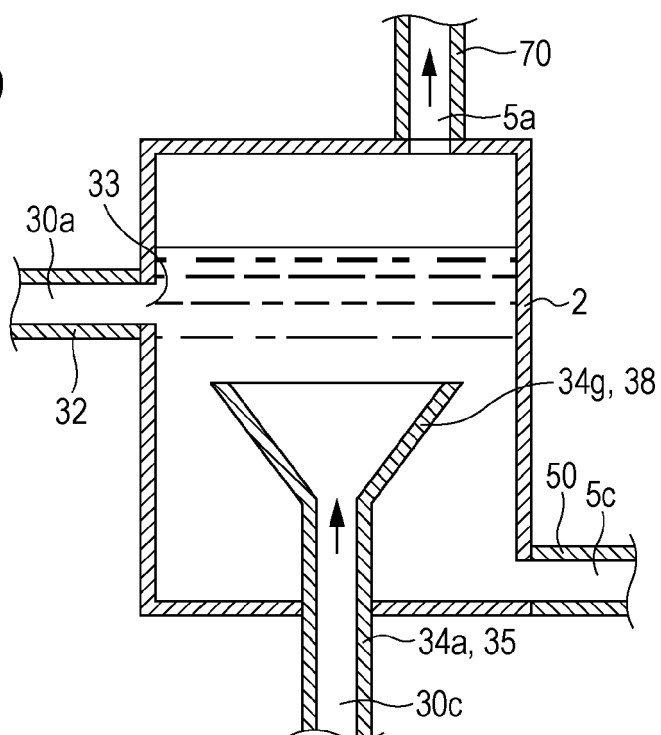


FIG. 10

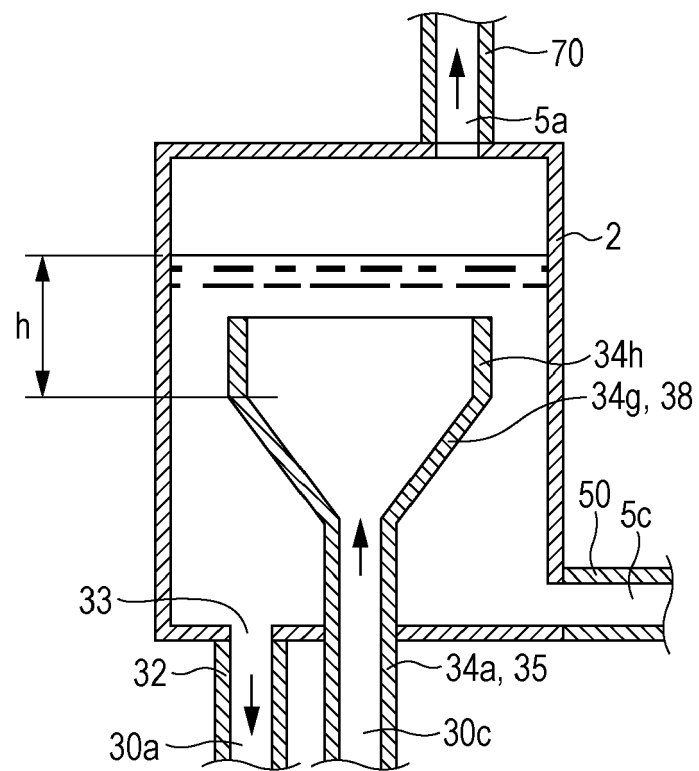


FIG. 11

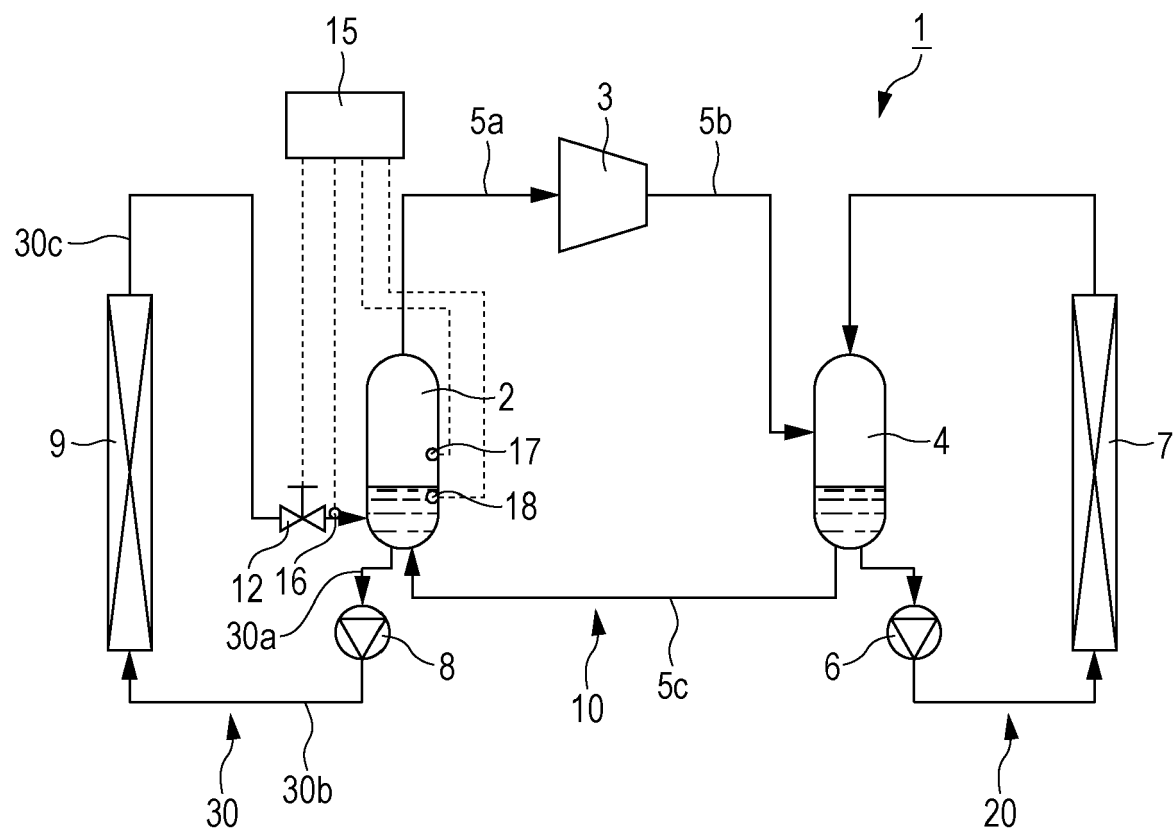


FIG. 12

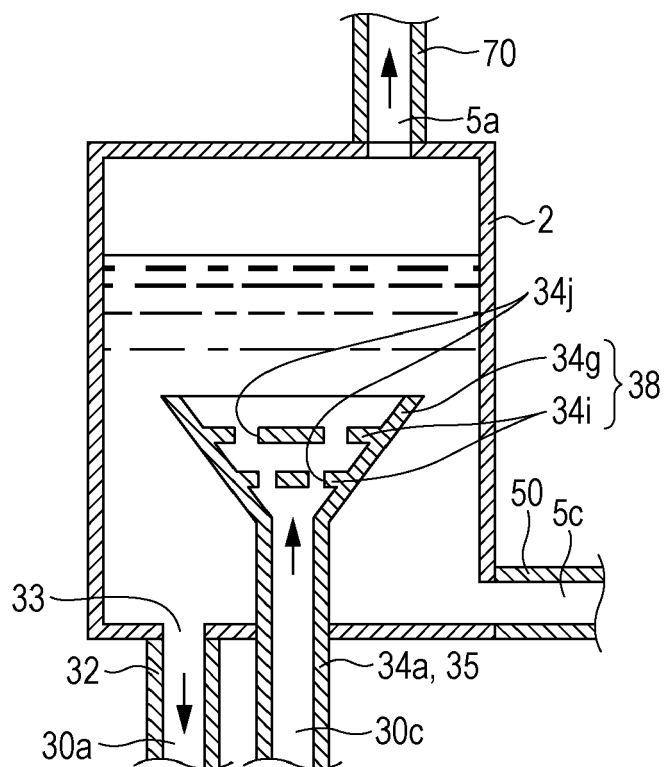


FIG. 13

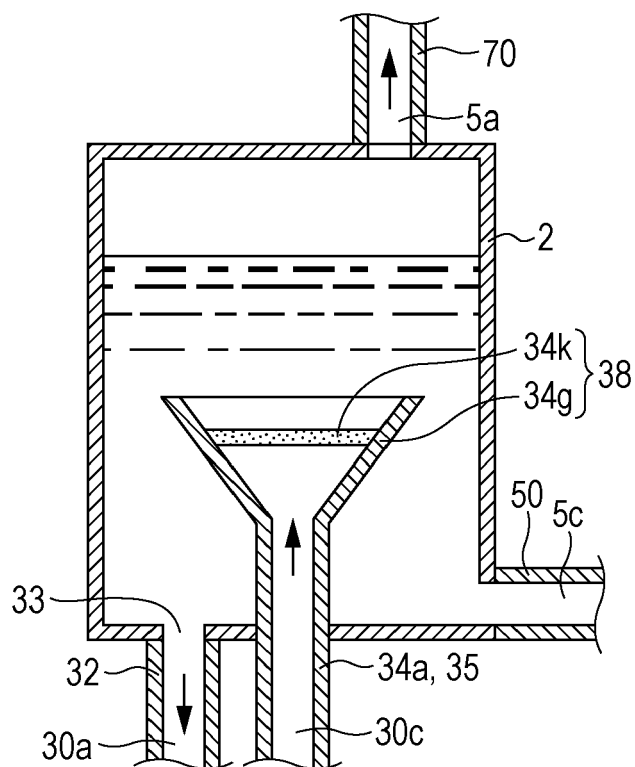


FIG. 14

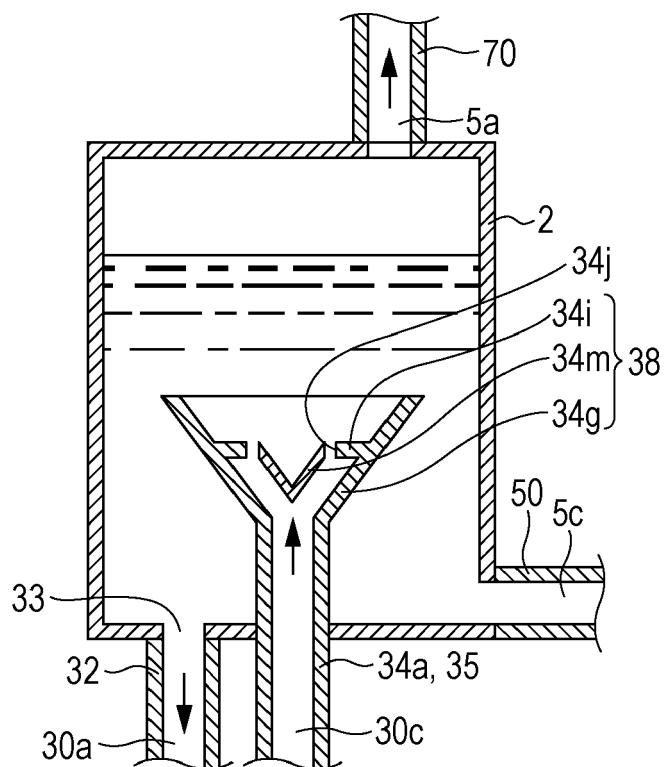


FIG. 15

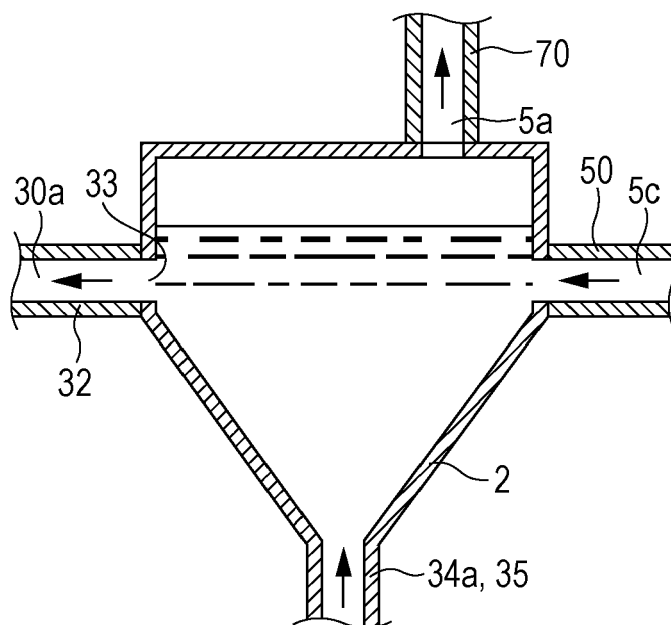


FIG. 16

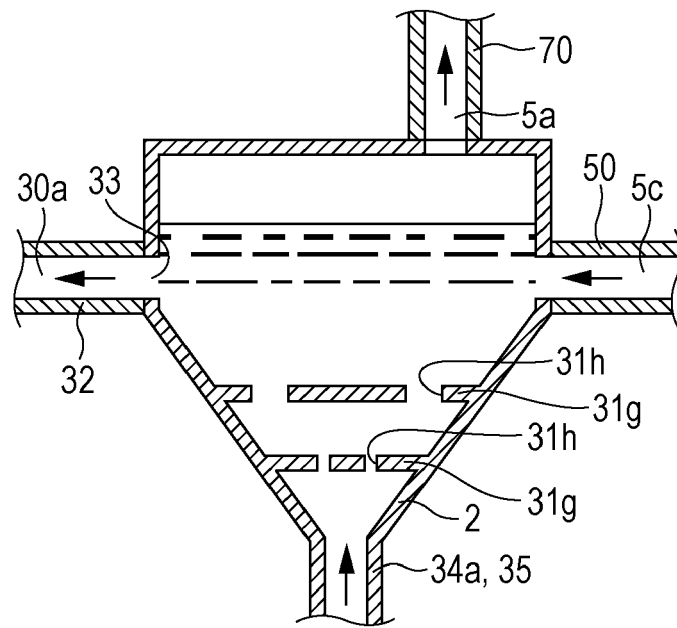


FIG. 17

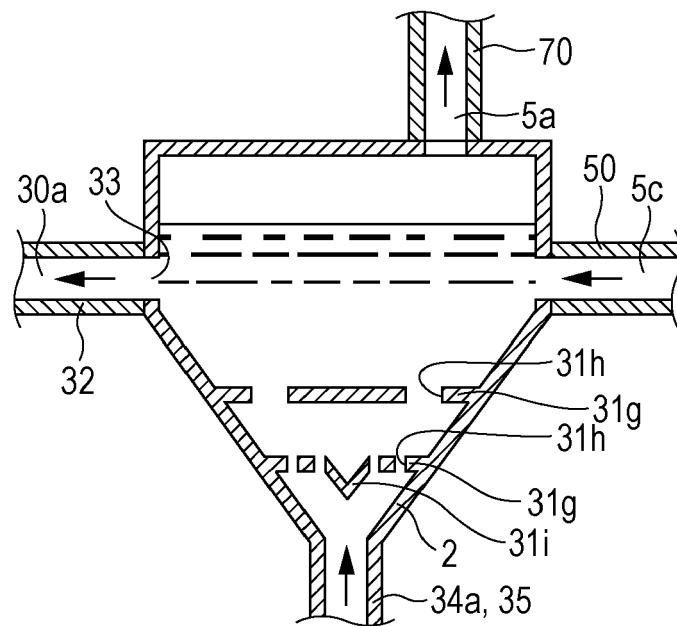


FIG. 18

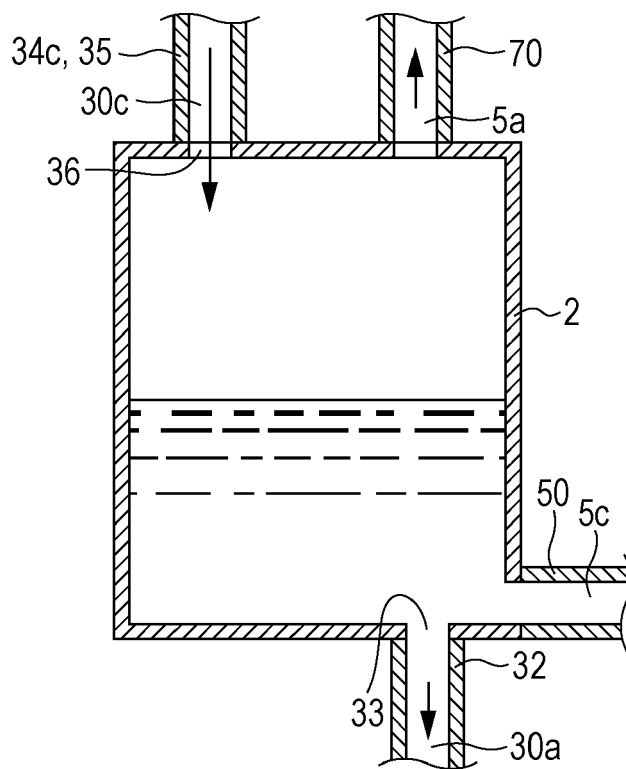


FIG. 19

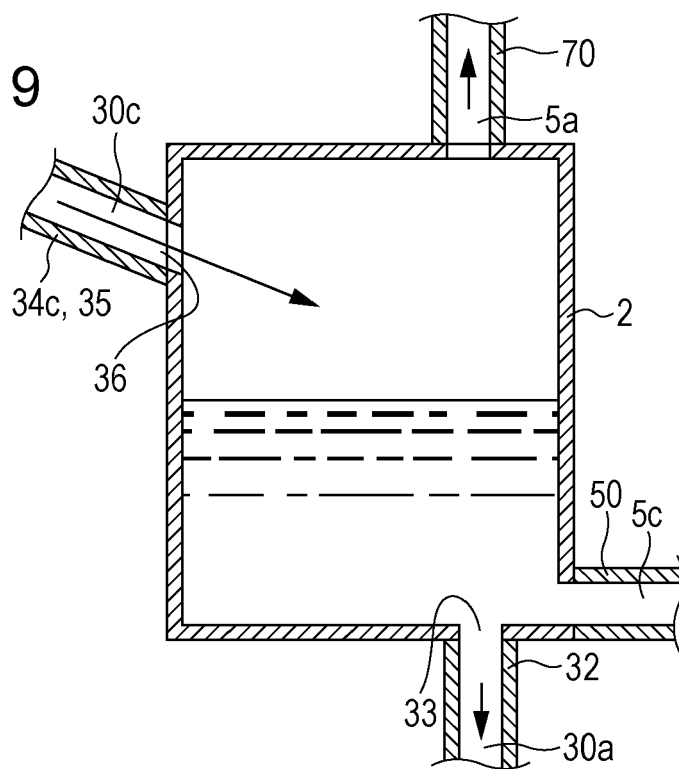


FIG. 20

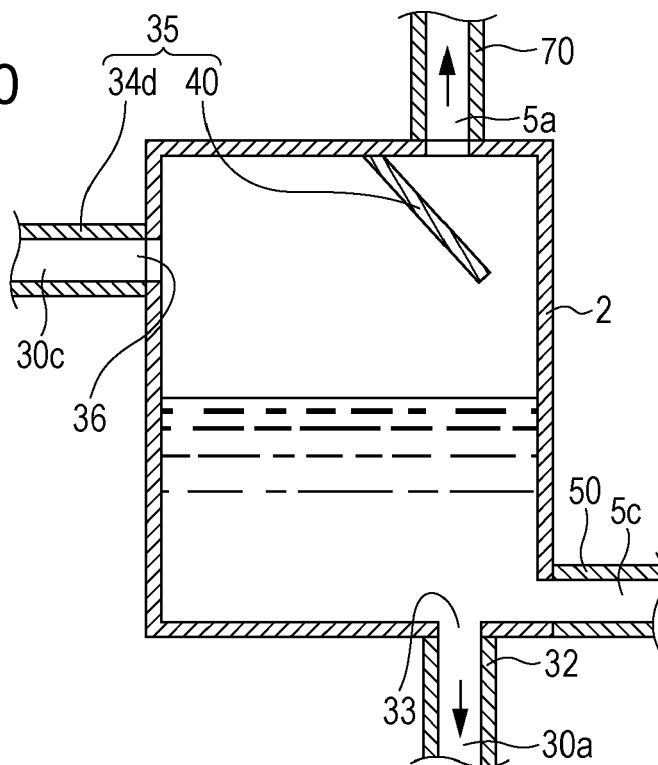


FIG. 21

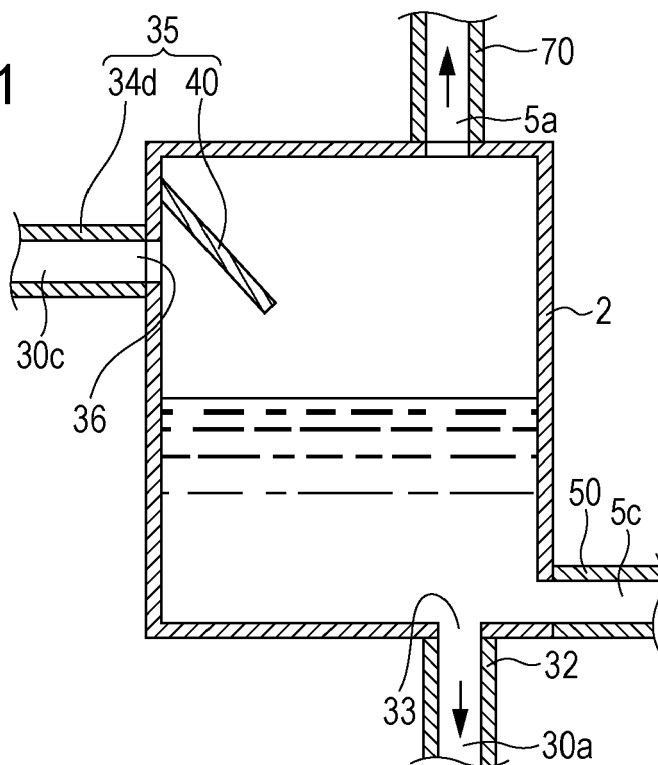


FIG. 22

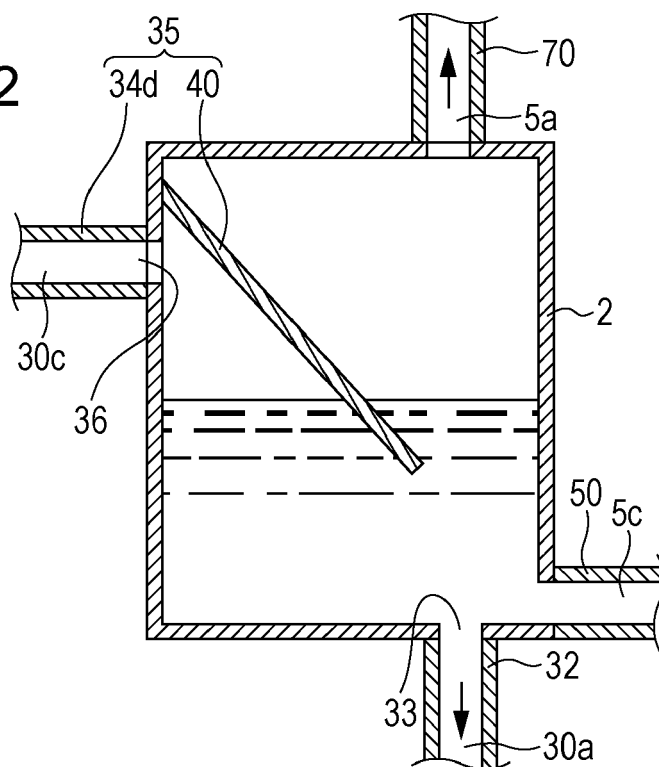


FIG. 23

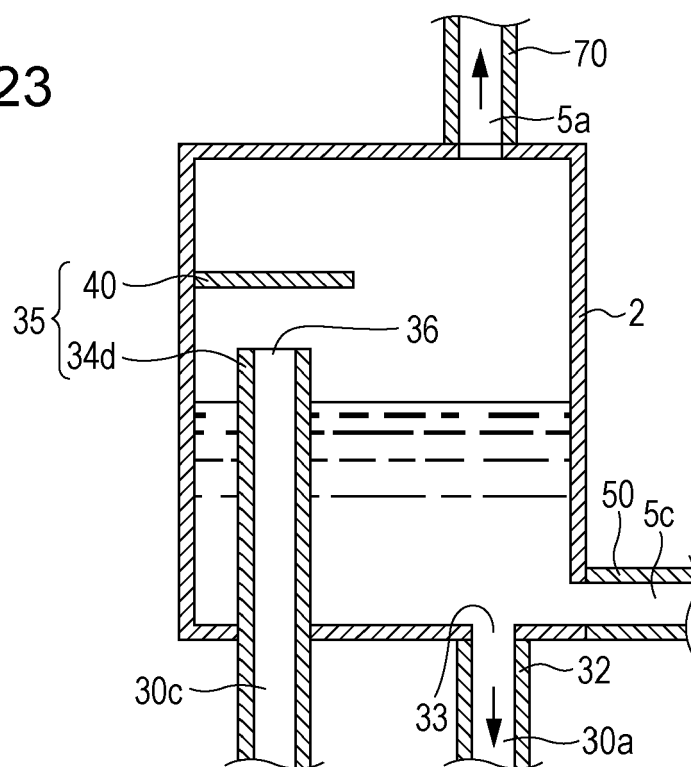
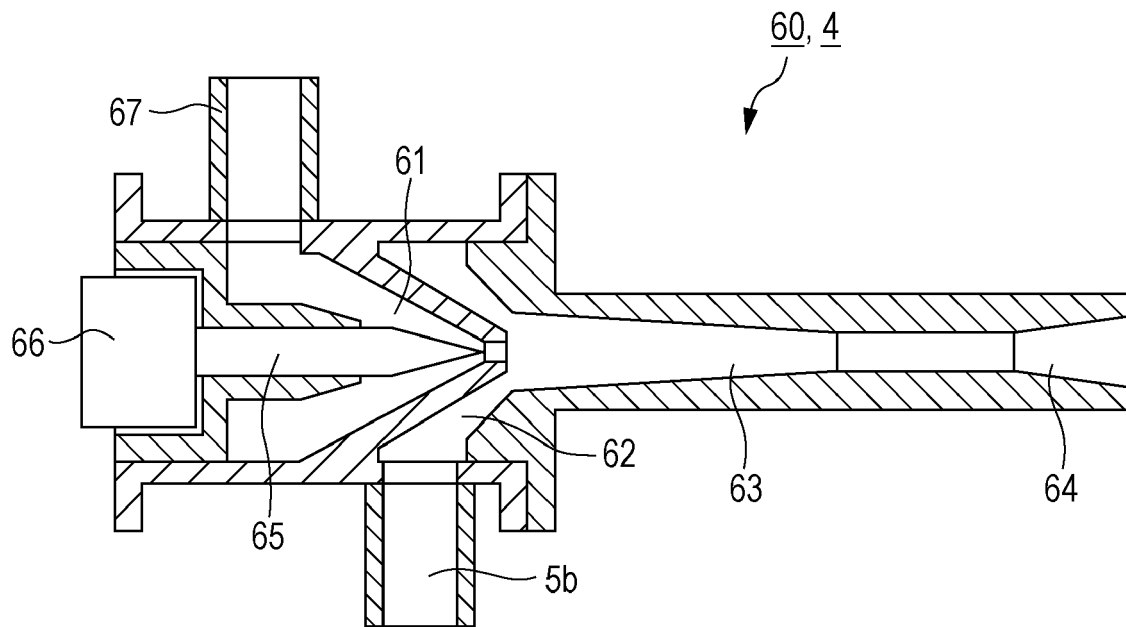


FIG. 24





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Y	* abstract; figure 1 * -----	4-13,15	
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A	US 5 778 696 A (CONNER LEO B [US]) 14 July 1998 (1998-07-14) * the whole document *	1-15	
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			F25B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 February 2015	Examiner Lucic, Anita
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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