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(54) GAS REFRIGERANT SEPARATOR, GAS REFRIGERANT SEPARATOR-CUM-REFRIGERANT FLOW DIVIDER, EXPANSION VALVE, AND REFRIGERATION DEVICE

(57) A gas refrigerant separatar-cum-refrigerant flow divider (DR) includes an inlet chamber (10) having a circular cross section, a speed increasing chamber (20) having a circular cross section, and an outlet chamber (30) having a circular cross section, which are coaxially arranged in series. The outlet chamber (30) introduces refrigerant from a refrigerant inlet port (14) and guides and swirls the refrigerant along an inner wall surface of the outlet chamber (30). The speed increasing chamber (20) increases the speed of a swirling refrigerant flow sent from the inlet chamber (10) and jets the swirling refrigerant flow into the outlet chamber (30) through a communication port (21), which is formed at the distal end of the speed increasing chamber (20). The diameter of the outlet chamber (30) is greater than the diameter of the communication port (21) at the distal end of the speed increasing chamber (20). The gas refrigerant separator-cum-refrigerant flow divider (DR) has a gas refrigerant extracting pipe (Pg) for extracting gas refrigerant from an axial portion of the swirling refrigerant flow and a refrigerant outlet pipe (Pd) for directing the refrigerant to the exterior after extraction of the gas refrigerant.

Fig.8(a)

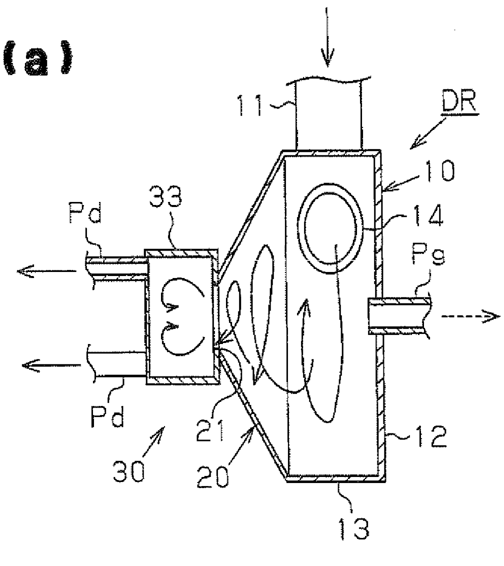

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Fig.8(b)

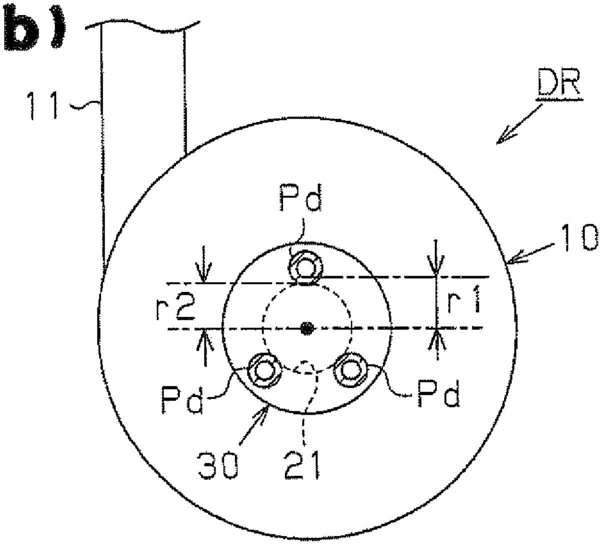
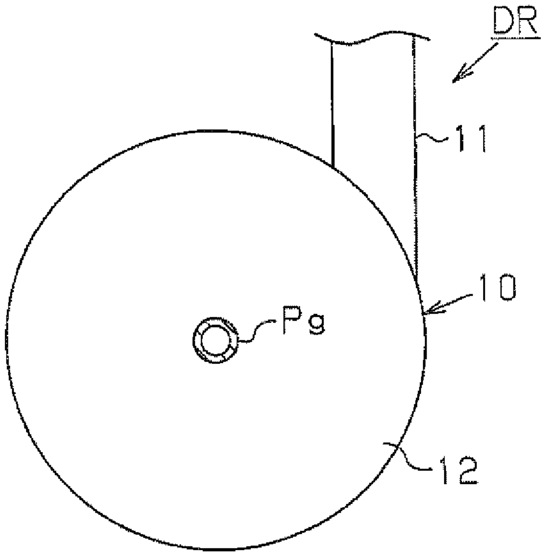


Fig.8(c)



Description

TECHNICAL FIELD

[0001] The present invention relates to a gas refrigerant separator for separating gas refrigerant from refrigerant in a two-phase gas-liquid state, a gas refrigerant separator-cum-refrigerant flow divider employing a gas refrigerant separating mechanism of the aforementioned gas refrigerant separator, an expansion valve combined with the gas refrigerant separator-cum-refrigerant flow divider, and a refrigerating apparatus using the gas refrigerant separator, the gas refrigerant separator-cum-refrigerant flow divider, or the expansion valve.

BACKGROUND ART

[0002] Patent Document 1 discloses a conventional refrigerating apparatus. In the refrigerating apparatus, refrigerant is divided into multiple flow paths after the refrigerant has been discharged from an expansion valve. At this stage, gas refrigerant is separated from the refrigerant and liquid refrigerant is distributed to a plurality of refrigerant passages of an evaporator, thus improving heat exchange efficiency of the evaporator. A gas refrigerant separator described in Patent Document 1 separates gas from liquid by means of a refrigerant flow divider. That is, the gas refrigerant separator functions also as a gas-liquid separator. In the gas refrigerant separator, after refrigerant in a two-phase gas-liquid state passes through the expansion valve, the refrigerant is sent into an upper portion of a cylindrical tank-like container and caused to swirl in the container. This centrifugally gathers liquid refrigerant to the vicinity of a wall surface of the container. The refrigerant is then gravitationally directed to and retained in a lower portion of the container. Gas refrigerant is gathered at the center of the swirling refrigerant flow. After such gas-liquid separation, the gas refrigerant is extracted from the central portion of the refrigerant flow and the liquid refrigerant, which is maintained in the lower portion of the container, is distributed to the refrigerant passages of the evaporator through flow dividing pipes. Then, the gas refrigerant, which has been removed from the gas refrigerant separator, is introduced into a gas header at the outlet of the evaporator. The gas refrigerant separator described in Patent Document 1, which is configured in the above-described manner, uneven refrigerant distribution in the refrigerant passages of the evaporator is prevented and the amount of the gas refrigerant contained in the refrigerant sent to the refrigerant passages is decreased. This enhances the heat exchange efficiency of the evaporator.

PRIOR ART DOCUMENT

Patent Document

[0003]

Patent Document 1: Japanese Laid-Open Patent Publication No. 2008-196762 [Summary of the Invention]

Problems that the Invention is to Solve

[0004] However, the above-described gas refrigerant separator separates gas from liquid using centrifugal force and gravity acting on the refrigerant flow. As a result, if the gas refrigerant separator is mounted in the refrigerating apparatus in a mounting direction offset from a predetermined direction, smooth gas-liquid separation is hampered. To prevent this, the gas refrigerant separator must be mounted in a strictly accurate mounting direction, which complicates mounting of the gas refrigerant separator in the refrigerating apparatus.

[0005] Accordingly, it is an objective of the present invention to provide a gas refrigerant separator that can be mounted in a refrigerating apparatus without strict accuracy in the mounting direction, a gas refrigerant separator-cum-refrigerant flow divider incorporating the gas refrigerant separator, and an expansion valve combined with the gas separator or the gas refrigerant separator-cum-refrigerant flow divider. It is another objective of the invention to provide a refrigerating apparatus having the gas refrigerant separator, the gas refrigerant separator-cum-refrigerant flow divider, or the expansion valve.

Means for Solving the Problems

[0006] A gas refrigerant separator according to the present invention includes an inlet chamber, a speed increasing chamber, an outlet chamber, a refrigerant inlet port, a refrigerant outlet pipe, and a gas refrigerant extracting pipe. The inlet chamber guides refrigerant in a two-phase gas-liquid state along an inner wall surface of a peripheral wall of a chamber having a circular cross section. The refrigerant is caused to swirl along the inner wall surface. The speed increasing chamber has a circular cross section and is joined coaxially with the inlet chamber in the axial direction. The speed increasing chamber increases the speed of a swirling refrigerant flow directed from the inlet chamber into the speed increasing chamber. The outlet chamber is joined coaxially with the speed increasing chamber in the axial direction and has a circular cross section. The outlet chamber receives the swirling refrigerant flow flowing through a communication port formed at a distal end of the speed increasing chamber. The diameter of the outlet chamber is greater than the opening diameter of the communication port. The refrigerant inlet port is formed in the inner wall surface of the peripheral wall of the inlet chamber. The refrigerant outlet pipe discharges the refrigerant from the outlet chamber after gas refrigerant has been separated and extracted from the refrigerant. The gas refrigerant extracting pipe extracts the gas refrigerant collected at a center portion of the swirling refrigerant flow.

[0007] In the gas refrigerant separator, which is configured as described above, a two-phase gas-liquid flow is caused to proceed along the inner wall surface of the inlet chamber, which has a circular cross section, at a flow speed sufficiently great for swirling in the inlet chamber without being influenced by gravity. This collects liquid refrigerant substantially in the vicinity of the inner wall surface of the peripheral wall and gathers only gas refrigerant at a middle portion of the swirling flow. The center of the swirling flow, which has been generated in the inlet chamber, does not necessarily correspond to the center of the gas refrigerant separator. However, since the swirling flow gains speed in the speed increasing chamber, gas-liquid separation is further promoted between the vicinity of the inner wall surface of the peripheral wall and the central portion. The center of the swirling flow thus becomes positioned approximately at the central axis of the gas refrigerant separator, homogenizing a liquid membrane. After exiting the speed increasing chamber, the refrigerant flows into the outlet chamber, which has an inner diameter greater than the opening diameter of the communication port of the speed increasing chamber. This produces an axisymmetric refrigerant flow in the outlet chamber with respect to the center of the outlet chamber. The center of the swirling refrigerant flow in the gas refrigerant separator thus becomes approximately located at the axis of the gas refrigerant separator and stabilizes. This prevents influence by gravity, thus ensuring exclusive collection of gas refrigerant at the central portion of the swirling flow and stable extraction of gas refrigerant from the central portion of the swirling flow. Also, liquid-rich refrigerant, which has been produced through gas refrigerant separation and extraction, is directed from the outlet chamber to the exterior. As a result, a gas refrigerant separator according to the present invention may be mounted without strict accuracy in the mounting direction. Handling of the gas refrigerant separator is thus facilitated.

[0008] The speed increasing chamber is preferably configured to increase the speed of the swirling flow by causing the refrigerant that has been directed from the inlet chamber to swirl along an inner wall surface of a peripheral wall shaped like a surface tapered or curved toward the communication port. In this configuration, the tapered or curved surface having a distally decreasing diameter increases the swirling speed of the refrigerant flow, thus further stabilizing the center of the swirling refrigerant flow. This allows setting of the mounting direction with less strict accuracy and ensures stable separation of gas refrigerant.

[0009] The outlet chamber preferably has a cylindrical shape, and the diameter of the communication port of the speed increasing chamber and the diameter and the axial dimension of the outlet chamber are preferably selected such that the refrigerant that has been directed from the speed increasing chamber is caused to swirl in the outlet chamber and the center portion of the swirling contains only the gas refrigerant. This configuration is employed when the diameter of the communication port is not significantly small, and the outlet chamber has a comparatively great diameter. This shape of the outlet chamber will be referred to as the basic configuration III herein (see Fig. 4). In this case, in a refrigerant jet flow from the speed increasing chamber to the outlet chamber, liquid refrigerant strikes against the inner wall surface of the peripheral wall via the centrifugal force produced by the swirling flow and gas refrigerant is blasted from the central portion. As a result, in the outlet chamber, liquid containing refrigerant swirls along the inner wall surface of the peripheral wall and only gas refrigerant gathers at an axial portion of the outlet chamber. This ensures stable extraction of the gas refrigerant from any portion of the flow from the inlet chamber to the outlet chamber. However, if the gas refrigerant is extracted from the speed increasing chamber, the gas refrigerant extracting pipe must extend into the speed increasing chamber and thus may hamper swirling of the refrigerant.

[0010] The outlet chamber preferably has a conical shape gradually enlarging from the speed increasing chamber toward the distal end, and the diameter of the communication port of the speed increasing chamber and the maximum diameter and the axial dimension of the outlet chamber are preferably selected such that the refrigerant that has been directed from the speed increasing chamber is caused to swirl in the outlet chamber and that a middle portion of the swirling contains only the gas refrigerant. This configuration is also employed if the communication port has a moderate opening diameter and the outlet chamber has a comparatively great diameter. This shape of the outlet chamber will be referred to as the basic configuration IV herein (see Fig. 4). In this case, in a refrigerant flow jet from the speed increasing chamber to the outlet chamber, liquid refrigerant is caused to flow along the wall surface by centrifugal force and gas refrigerant is blasted from the middle portion. Further, in the outlet chamber, a liquid membrane is formed along the inner wall surface of the peripheral wall and only gas refrigerant is collected at the middle portion of the outlet chamber. As a result, gas-liquid separation is carried out further reliably in the outlet chamber, thus ensuring stable extraction of the gas refrigerant from the outlet chamber.

[0011] That the peripheral wall of the speed increasing chamber and the peripheral wall of the speed increasing chamber are preferably formed by wall surfaces that form a smoothly curved surface with the communication port located therebetween. This configuration decreases unnecessary energy loss in refrigerant flow from the speed increasing chamber into the outlet chamber. As a result, intensity of the swirling refrigerant flow is maintained when the refrigerant flows into the outlet chamber.

[0012] Alternatively, when the communication port of the speed increasing chamber and the outlet chamber are joined to each other by the smoothly curved surface, as has been described, the peripheral wall of the speed increasing chamber and the peripheral wall of the outlet chamber may be formed integrally with each other. In this case, the inlet chamber is formed separately from the speed increasing chamber and the outlet chamber and joined to the speed increasing chamber. This configuration eliminates a joint from the smooth surface curved at the communication port, thus decreasing fluid turbulence throughout the path from the communication port of the speed increasing chamber to the outlet chamber. As a result, a swirling refrigerant flow is directed from the speed increasing chamber into the outlet chamber in a stable state.

[0013] The diameter of the communication port of the speed increasing chamber and the diameter and the axial dimension of the outlet chamber are preferably selected such that, in the outlet chamber, the refrigerant directed from the speed increasing chamber is blown toward and caused to strike the peripheral wall through centrifugal force produced by the swirling flow and is thus stirred in the outlet chamber. This configuration is employed when the diameter of the communication port is not significantly small and the outlet chamber has a comparatively small diameter. This shape of the outlet chamber will be referred to as the basic configuration II herein (see Fig. 4). In this case, in a refrigerant jet flow from the speed increasing chamber to the outlet chamber, liquid refrigerant strikes against the inner wall surface of the peripheral wall by centrifugal force produced by the swirling flow and gas refrigerant is blasted from a central portion. As a result, in the outlet chamber, the refrigerant hits the inner wall surface of the peripheral wall after having been struck against the inner wall surface of the peripheral wall. The refrigerant is thus stirred through impacts or striking. Also, the refrigerant forms an axisymmetric flow moving from the inner wall surface of the peripheral wall toward the center of the outlet chamber, thus stabilizing the swirling flow in the inlet chamber and the speed increasing chamber. Also, gas refrigerant is stably extracted from the middle portion of the inlet chamber.

[0014] The diameter of the communication port of the speed increasing chamber is preferably selected such that, in the outlet chamber, the refrigerant directed from the speed increasing chamber is subjected to a throttle effect in the communication port and thus sprayed in a homogeneous gas-liquid distribution state. This configuration is employed if the communication port has an extremely small diameter, regardless of whether the diameter of the outlet chamber is comparatively small or great. This shape of the outlet chamber will be referred to as the basic configuration I herein (see Fig. 4). In this configuration, a refrigerant flow jet from the speed increasing chamber into the outlet chamber is caused to swirl and throttled at the communication port. The refrigerant is thus jetted from the middle portion of the communication port, containing liquid refrigerant, and strikes the wall surface of the outlet chamber facing the communication port. The refrigerant then flows along the inner wall surface of the peripheral wall. As a result, a refrigerant flow having even gas-liquid distribution is produced in the outlet chamber. Also, the refrigerant flow becomes axisymmetric with respect to the axis of the outlet chamber, thus stabilizing the swirling flow in the inlet chamber and the speed increasing chamber. Further, this ensures stable extraction of gas refrigerant from the middle portion of the inlet chamber.

[0015] The gas refrigerant extracting pipe is preferably configured to extract the gas refrigerant that has been separated and collected at a center of the refrigerant swirling in the inlet chamber. This configuration may be employed for the outlet chamber of any one of the basic configurations I to IV. Specifically, the inlet chamber has a proportion of gas refrigerant that is greater to an extreme extent than the proportion of liquid refrigerant and may cause focal concentration of the liquid refrigerant. However, by removing gas from the inlet chamber, the proportion of the gas refrigerant flowing into the speed increasing chamber is decreased. This facilitates formation of a homogenous liquid membrane and stabilizes gas-liquid distribution in the speed increasing chamber. As a result, the center of the swirling in the inlet chamber and the speed increasing chamber is stabilized, and stable extraction of gas refrigerant is ensured. Further, if the flow speed of the refrigerant introduced through a refrigerant inlet port is extremely great in the case in which gas refrigerant is extracted from the inlet chamber, the pressure in the vicinity of the refrigerant inlet port may easily drop. Accordingly, in this case, the center of the swirling flow may be set offset toward the side corresponding to the refrigerant inlet port.

[0016] That the gas refrigerant extracting pipe is preferably configured to extract the gas refrigerant that has been separated and collected at a center of the refrigerant swirling in the outlet chamber. This configuration may be employed for the outlet chamber of the basic configuration III or IV. In this configuration, a stable gas refrigerant flow is formed along the axis of the outlet chamber from the inlet to the gas refrigerant extracting pipe. This stabilizes the swirling flow in the outlet chamber, thus ensuring stable extraction of gas refrigerant.

[0017] Alternatively, the configuration described below may be employed for the above-described case in which the gas refrigerant extracting pipe is arranged in the outlet chamber. Specifically, the gas refrigerant extracting pipe may be configured to extract the gas refrigerant that has been separated and collected at the middle of the swirling refrigerant in the outlet chamber. The refrigerant outlet pipe may be formed as an outlet pipe with a large diameter and connected to the outlet chamber to extract liquid refrigerant swirling around the gas refrigerant extracting pipe. Further, the gas refrigerant extracting pipe may be inserted in the refrigerant outlet pipe to form an inner pipe of a double pipe structure having the refrigerant outlet pipe as an outer pipe. This simplifies the configuration of the gas refrigerant separator.

[0018] That the inlet chamber preferably has a cylindrical shape. This simplifies the configuration of the inlet chamber, thus facilitating manufacture of the gas refrigerant separator.

[0019] The inlet chamber preferably substantially has a conical shape having a diameter increasing toward the speed increasing chamber. In this configuration, the inlet chamber having the conical shape with a gradually increasing diameter effectively guides the refrigerant swirling in the inlet chamber to the speed increasing chamber. This stabilizes jet flow from the communication port of the speed increasing chamber into the outlet chamber, thus ensuring stable extraction of gas refrigerant.

[0020] The inlet chamber preferably has an inclined cylindrical shape, and the inlet chamber is preferably inclined in a direction in which refrigerant flow introduced therein is guided to the speed increasing chamber. This configuration also stabilizes the swirling refrigerant flow introduced through the refrigerant inlet port, compared to the inlet chamber having the above-described cylindrical shape. As a result, gas refrigerant is stably extracted.

[0021] The inlet chamber preferably has a flow adjusting portion that is formed in the refrigerant inlet port to apply a swirling component to a refrigerant flow introduced therein. In this configuration, a swirling component is provided in advance to the refrigerant flowing into the inlet chamber. This increases the swirling speed in the inlet chamber. As a result, refrigerant swirling is stabilized, and gas refrigerant is stably extracted.

[0022] A central part of an inner wall surface of a side wall of the inlet chamber at the side opposite to the speed increasing chamber preferably has an outwardly projected partially spherical shape. In this configuration, the center of the swirling refrigerant flow in the inlet chamber is corrected toward the middle of the outwardly projected partially spherical portion. As a result, the center of the swirling refrigerant flow is stabilized in the vicinity of the center axis of the gas refrigerant separator.

[0023] A central part of an inner wall surface of a side wall of the inlet chamber at the side opposite to the speed increasing chamber preferably has an inwardly projected partially spherical shape. In this configuration, the inwardly projected partially spherical portion reduces the size of the space corresponding to the central portion of the inlet chamber where minimum pressure acts. As a result, a flow along the surface of the inwardly projected partially spherical portion is formed. Stabilization of a swirling refrigerant flow is thus facilitated.

[0024] A central part of an inner wall surface of a side wall of the outlet chamber that faces the communication port of the speed increasing chamber preferably has an outwardly projected partially spherical shape. In this configuration, the center axis of the swirling refrigerant flow generated in the outlet chamber is corrected toward the middle of the outwardly projected partially spherical portion. As a result, the center of the swirling refrigerant flow is stabilized in the vicinity of the center axis of the gas refrigerant separator.

[0025] A central part of an inner wall surface of a side wall of the outlet chamber that faces the communication port of the speed increasing chamber preferably has an inwardly projected partially spherical shape. In this configuration, the inwardly projected partially spherical portion reduces the size of the space corresponding to the central portion of the outlet chamber where minimum pressure acts. The inwardly projected partially spherical portion also forms a guide wall. As a result, a flow along the surface of the inwardly projected partially spherical portion is formed and stabilization of a swirling refrigerant flow is facilitated.

[0026] A step is preferably formed in a joint portion between the inlet chamber and the speed increasing chamber such that the diameter of the inlet chamber is greater than the diameter of the speed increasing chamber. In this configuration, the step retains the refrigerant flow before the refrigerant enters the speed increasing chamber, thus increasing the swirling force produced by the refrigerant. This stabilizes the swirling and ensures stable extraction of gas refrigerant.

[0027] An annular groove portion having a diameter greater than both the diameter of the inlet chamber and the diameter of the speed increasing chamber is preferably formed in a joint portion between the inlet chamber and the speed increasing chamber. Also in this configuration, the annular groove portion retains the refrigerant flow before the refrigerant enters the speed increasing chamber, thus increasing the swirling force generated by the refrigerant, as in the case of the above-described configuration. This stabilizes the swirling and ensures stable extraction of gas refrigerant.

[0028] A straight communication passage having a diameter substantially equal to the diameter of the communication port is preferably formed in a joint portion between the speed increasing chamber and the outlet chamber. In this configuration, the swirling flow is stabilized in the straight communication passage having a uniform cross-sectional area before flowing into the outlet chamber. This stabilizes gas refrigerant extraction.

[0029] A conical portion having a diameter increasing toward the outlet chamber, starting from the diameter of the communication port, is preferably formed in a joint portion between the speed increasing chamber and the outlet chamber, wherein the conical portion is connected directly to the outlet chamber. In this configuration, the centrifugal force produced by the swirling flow allows liquid refrigerant to flow into the outlet chamber without separating from the wall surface. This ensures further reliable gas-liquid separation in the outlet chamber. As a result, the configuration stabilizes extraction of gas refrigerant from the outlet chamber.

[0030] The speed increasing chamber and the outlet chamber are preferably formed separately from each other and joined together at a joint portion between the speed increasing chamber and the outlet chamber. This configuration allows joining of the components, including the inlet chamber, the speed increasing chamber, and the outlet chamber, at small-diameter portions. Such joining is thus facilitated and a structural defect such as refrigerant leak area is easily avoided.

[0031] A filter for removing undesirable matter from the refrigerant is preferably mounted in the gas refrigerant separator. This configuration allows omitting of a device employed specifically for the filter, which must be arranged in the refrigerant circuit.

[0032] A gas refrigerant separator-cum-refrigerant flow divider according to the present invention characterized by the following features. The refrigerant outlet pipe of the above described gas refrigerant separator is configured as a plurality of flow dividing pipes connected to a plurality of refrigerant passages in an evaporator. The flow dividing pipes are spaced apart at equal intervals along a circumference spaced from the axis by a certain distance. The flow dividing pipes are formed such that the radius of an inscribed circle of the flow dividing pipes is greater than the radius of the communication port and that the radius of the outlet chamber is smaller than or equal to the radius of an inscribed circle of the refrigerant inlet port. In this configuration, the radius of the circumference on which the flow dividing pipes are arranged is greater than the radius of the communication pipe. This decreases the frequency at which a refrigerant flow directly enters the flow dividing pipes when jetted into the outlet chamber through the communication port in a gas refrigerant separator corresponding to any one of the basic configurations I to IV. Also, the radius of the outlet chamber is smaller than or equal to the radius of the inlet chamber. This ensures a sufficient swirling flow in the inlet chamber according to the law of conservation of angular momentum in a gas refrigerant separator corresponding to either one of the basic configurations III and IV. In this manner, the axisymmetric refrigerant flow about the axis of the outlet chamber is maintained and gas refrigerant extraction is thus stabilized. Also, flow division for the respective flow dividing pipes is performed on the axisymmetric refrigerant flow, which has been subjected to the gas refrigerant extraction and is thus liquid-refrigerant-rich. As a result, flow division performance is improved and uniformly divided flows are obtained.

[0033] In the gas refrigerant separator-cum-refrigerant flow divider, the outlet chamber is preferably formed such that the flow dividing pipes are arranged in the vicinity of the peripheral wall of the outlet chamber. In this configuration, the flow dividing pipes are arranged at positions where an axisymmetric refrigerant flow is easily generated and the refrigerant easily becomes rich in liquid refrigerant. This further enhances the refrigerant flow division performance.

[0034] In the gas refrigerant separator-cum-refrigerant flow divider, the communication port of the speed increasing member may be formed such that the communication port has an inclined end surface. In this configuration, the inclined end surface allows improvement in the flow division characteristics and regulation of the amounts of the divided flows distributed to the respective flow dividing pipes.

[0035] An expansion valve according to the present invention has an inlet pipe, an outlet pipe, and a throttle portion formed in the expansion valve. The expansion valve is characterized in that the above described gas refrigerant separator is connected to the outlet pipe, a refrigerant jet flow through the throttle portion being introduced into the inlet chamber via the outlet pipe. In this configuration, a refrigerant jet flow is introduced into the inlet chamber through the throttle portion of the expansion valve. This increases intensity of the swirling flow in the inlet chamber and thus stabilizes the swirling flow. As a result, the gas separator-cum-refrigerant flow divider is mounted with less strict accuracy in its mounting direction. Also, simply by joining the expansion valve to the gas refrigerant separator using a short straight pipe, an effect of component integration is obtained.

[0036] An expansion valve according to the present invention has an inlet pipe, an outlet pipe, and a throttle portion formed in the expansion valve. The expansion valve is characterized in that the above described gas refrigerant separator-cum-refrigerant flow divider is connected to the outlet pipe, a refrigerant jet flow through the throttle portion being introduced into the inlet chamber via the outlet pipe. In this configuration, a refrigerant jet flow is introduced into the inlet chamber through the throttle portion of the expansion valve. This increases intensity of the swirling flow in the inlet chamber and thus stabilizes the swirling flow. As a result, the gas separator-cum-refrigerant flow divider is mounted with less strict accuracy in its mounting direction. Also, simply by joining the expansion valve to the gas refrigerant separator-cum-refrigerant flow divider using a short straight pipe, an effect of component integration is obtained.

[0037] A refrigerating apparatus according to the present invention is characterized in the following features. The above described gas refrigerant separator is connected to an outlet side of an expansion valve. The refrigerant outlet pipe is connected to a plurality of refrigerant pipes of an evaporator through the flow dividing pipes. The gas refrigerant extracting pipe bypasses refrigerant passages for directing divided flows of the refrigerant and is connected to an outlet side of the evaporator. In this configuration, the gas refrigerant separator extracts gas refrigerant from a two-phase gas-liquid flow, thus decreasing the gas refrigerant contained in the refrigerant flowing into the evaporator. This improves heat exchange efficiency of the evaporator. The evaporator is a heat exchanger that uses latent heat produced through a phase change in refrigerant from liquid to gas. Accordingly, as more liquid refrigerant is contained in supplied refrigerant, the heat exchanger operates more effectively. Also, if an evaporator receives a great amount of gas refrigerant as in a typical refrigerating apparatus, the great volume of the gas refrigerant results in disadvantageous increases in pressure loss.

[0038] A refrigerating apparatus according to the present invention may be configured to have the following features. The gas refrigerant separator-cum-refrigerant flow divider according to any one of claims 26 to 28 is connected to an outlet side of an expansion valve. The flow dividing pipes are connected to a plurality of refrigerant passages in an evaporator. The gas refrigerant extracting pipe bypasses the refrigerant passages and is connected to an outlet side of the evaporator. As in the above-described other configurations, this configuration allows the gas refrigerant separator-cum-refrigerant flow divider to extract gas refrigerant from refrigerant, thus decreasing the gas refrigerant in the refrigerant flowing into the evaporator. This improves heat exchange efficiency of the evaporator for the same reasons as the reasons that have been described for the above-described cases. Further, refrigerant flow division performance is enhanced by employing the gas refrigerant separator-cum-refrigerant flow divider. The enhanced refrigerant flow division performance also improves the heat exchange efficiency of the evaporator.

[0039] A refrigerating apparatus according to the present invention may use the above described expansion valve, and the refrigerant outlet pipe may be connected to a plurality of refrigerant passages in an evaporator and that the gas refrigerant extracting pipe bypasses the refrigerant passages and is connected to an outlet side of the evaporator. As in the above-described other configurations, this configuration allows the gas refrigerant separator-cum-refrigerant flow divider, which employs the expansion valve, to extract gas refrigerant from refrigerant, thus decreasing the gas refrigerant contained in the refrigerant flowing into the evaporator. This improves heat exchange efficiency of the evaporator for the same reasons as the reasons that have been described for the above-described cases. Further, refrigerant flow division performance is enhanced by employing the expansion valve. The better refrigerant flow division performance also improves the heat exchange efficiency of the evaporator.

[0040] The gas refrigerant extracting pipe may be connected directly to an outlet pipe of the evaporator. In this configuration, the gas refrigerant sent from the gas refrigerant extracting pipe is mixed with the refrigerant at the outlet side of the evaporator and then drawn into the compressor. Accordingly, the amounts of the respective refrigerants may be adjusted such that the mixed refrigerant exhibits an appropriate degree of superheating. For example, a valve capable of adjusting the refrigerant flow amount may be arranged in the bypass circuit through which the gas refrigerant extracting pipe is connected to the outlet pipe of the evaporator. This enables maximum extraction of gas refrigerant from the gas refrigerant extracting pipe within such a range that liquid refrigerant is prevented from being mixed with the gas refrigerant. As a result, the heat exchange efficiency of the evaporator is further improved.

[0041] The gas refrigerant extracting pipe may be connected to an outlet pipe of the evaporator via a gas refrigerant passage formed in the evaporator. In this configuration, heat exchange with the air is carried out using change in sensible heat of the gas refrigerant extracted from the gas refrigerant extracting pipe. This correspondingly improves efficiency of the heat exchanger.

[0042] The gas refrigerant extracting pipe may be connected to an outlet pipe of the evaporator via a supercooling heat exchanger arranged at an inlet side of the expansion valve, and the supercooling heat exchanger may cause heat exchange with liquid refrigerant at an inlet side of the expansion valve. This configuration allows cooling of the refrigerant flowing into the expansion valve using sensible heat of the extracted gas refrigerant. Also, since the cooled refrigerant flowing into the expansion valve is less dry, intermittent noise caused by refrigerant in the expansion valve is decreased.

[0043] In the above described refrigerating apparatus, a flow control valve may be arranged in a circuit through which the gas refrigerant extracting pipe is connected to an outlet of the evaporator. In this configuration, by checking the degree of superheating of the refrigerant at the outlet side of the circuit, the amount of the refrigerant gas extracted from the gas refrigerant separator or the gas refrigerant separator-cum-refrigerant flow divider is easily maximized.

[0044] In the above described refrigerating apparatus, a refrigerant circuit may be configured as a heat pump cycle capable of performing a reversible cycle. A check valve for preventing a refrigerant flow from an outlet of the evaporator to the gas refrigerant extracting pipe is preferably arranged in a circuit through which the gas refrigerant extracting pipe is connected to the outlet of the evaporator. This configuration prevents discharge gas from bypassing a condenser when the refrigerant circuit is switched to operate the heat exchanger as the condenser instead of the evaporator.

[0045] In the above described refrigerating apparatus, a refrigerant circuit is preferably configured as a heat pump cycle capable of performing a reversible cycle, and a fully closable flow control valve is preferably arranged in a circuit through which the gas refrigerant extracting pipe is connected to an outlet of the evaporator, and that the flow control valve is fully closed in an operating cycle in which a refrigerant flow from the outlet of the evaporator to the gas refrigerant extracting pipe is produced.

EFFECTS OF THE INVENTION

[0046] The gas refrigerant separator according to the present invention is mounted in a refrigerating apparatus without strict accuracy in its mounting direction. Handling of the gas refrigerant separator is thus facilitated. The invention also provides a gas refrigerant separator-cum-refrigerant flow divider or an expansion valve employing the aforementioned gas refrigerant separator, as well as a refrigerating apparatus incorporating the gas refrigerant separator, the gas refrigerant separator-cum-refrigerant flow divider, or the expansion valve.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047]

Fig. 1(a) is an axial cross-sectional view showing a gas refrigerant separator according to a first embodiment of the present invention;

Fig. 1(b) is a side view showing the gas refrigerant separator corresponding to an outlet chamber;

Fig. 1(c) is a side view showing the gas refrigerant separator corresponding to an inlet chamber;

Fig. 2(a) is an axial cross-sectional view illustrating a flow path in the gas refrigerant separator of the first embodiment;

Fig. 2(b) is a cross-sectional view in a direction perpendicular to the axial direction illustrating a flow path in the gas refrigerant separator;

Fig. 3 is a diagram showing a refrigerant circuit in a refrigerating apparatus employing the gas refrigerant separator of the first embodiment;

Fig. 4 is a diagram illustrating the basic configurations of the outlet chamber in the gas refrigerant separators according to the invention;

Fig. 5(a) is an axial cross-sectional view showing a gas refrigerant separator according to a second embodiment of the invention;

Fig. 5(b) is a side view showing the gas refrigerant separator corresponding to an outlet chamber;

Fig. 5(c) is a side view showing the gas refrigerant separator corresponding to an inlet chamber;

Fig. 6(a) is an axial cross-sectional view illustrating a flow path in the gas refrigerant separator of the second embodiment;

Fig. 6(b) is a cross-sectional view in a direction perpendicular to the axial direction illustrating a flow path in the gas refrigerant separator;

Fig. 7 is a diagram showing a refrigerant circuit in a refrigerating apparatus employing the gas refrigerant separator of the second embodiment;

Fig. 8(a) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a third embodiment of the invention;

Fig. 8(b) is a side view showing the gas refrigerant separator-gas flow divider corresponding to an outlet chamber;

Fig. 8(c) is a side view showing the gas refrigerant separator-cum-refrigerant flow divider corresponding to an inlet chamber;

Fig. 9 is a diagram showing a refrigerant circuit in a refrigerating apparatus employing the gas refrigerant separator-cum-refrigerant flow divider of the third embodiment;

Fig. 10(a) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a fourth embodiment of the invention;

Fig. 10(b) is a side view showing the gas refrigerant separator-gas flow divider corresponding to an outlet chamber;

Fig. 10(c) is a side view showing the gas refrigerant separator-cum-refrigerant flow divider corresponding to an inlet chamber;

Fig. 11 is a diagram showing a refrigerant circuit in a refrigerating apparatus employing the gas refrigerant separator-cum-refrigerant flow divider of the fourth embodiment;

Fig. 12(a) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a fifth embodiment of the invention;

Fig. 12(b) is a side view showing the gas refrigerant separator-gas flow divider corresponding to an outlet chamber;

Fig. 12(c) is a side view showing the gas refrigerant separator-cum-refrigerant flow divider corresponding to an inlet chamber;

Fig. 13(a) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a sixth embodiment of the invention;

Fig. 13(b) is a side view showing the gas refrigerant separator-gas flow divider corresponding to an outlet chamber;

Fig. 13(c) is a side view showing the gas refrigerant separator-cum-refrigerant flow divider corresponding to an inlet chamber;

Fig. 14 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a seventh embodiment of the invention;

Fig. 15 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to an eighth embodiment of the invention;

Fig. 16 is a cross-sectional view showing an inlet chamber in a gas refrigerant separator-cum-refrigerant flow divider according to a ninth embodiment of the invention;

Fig. 17 is a cross-sectional view showing an inlet chamber in a gas refrigerant separator-cum-refrigerant flow divider according to a tenth embodiment of the invention;

Fig. 18 is a cross-sectional view showing an inlet chamber in a gas refrigerant separator-cum-refrigerant flow divider according to an eleventh embodiment of the invention;

Fig. 19 is a cross-sectional view showing an inlet chamber in a gas refrigerant separator-cum-refrigerant flow divider according to a twelfth embodiment of the invention;

Fig. 20 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a thirteenth embodiment of the invention;

Fig. 21 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a fourteenth embodiment of the invention;

Fig. 22 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a fifteenth embodiment of the invention;

Fig. 23 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a sixteenth embodiment of the invention;

Fig. 24 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a seventeenth embodiment of the invention;

Fig. 25(a) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to an eighteenth embodiment of the invention;

Fig. 25(b) is a side view showing the gas refrigerant separator-gas flow divider corresponding to an outlet chamber;

Fig. 26 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a nineteenth embodiment of the invention;

Fig. 27 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a twentieth embodiment of the invention;

Fig. 28 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a twenty-first embodiment of the invention;

Fig. 29 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a twenty-second embodiment of the invention;

Fig. 30(a) is a front view showing an expansion valve according to a twenty-third embodiment of the invention;

Fig. 30(b) is a side view showing the expansion valve;

Fig. 31 (a) is a cross-sectional view showing a portion of the expansion valve of the twenty-third embodiment;

Fig. 31(b) is an enlarged cross-sectional view showing a throttle portion of the expansion valve in a closed state;

Fig. 31(c) is an enlarged cross-sectional view showing the throttle portion of the expansion valve in an open state;

Fig. 32 is a diagram illustrating a refrigerant circuit of a refrigerating apparatus according to a twenty-fourth embodiment of the invention;

Fig. 33 is a diagram illustrating a refrigerant circuit of a refrigerating apparatus according to a twenty-fifth embodiment of the invention;

Fig. 34(a) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to a modification of the invention;

Fig. 34(b) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to another modification of the invention;

Fig. 34(c) is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to another modification of the invention;

Fig. 35 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to another modification of the invention;

Fig. 36(a) is a front cross-sectional view showing a portion of an expansion valve according to another modification of the invention;

Fig. 36(b) is a side cross-sectional view showing a portion of the expansion valve according to the modification of the invention;

Fig. 37 is an axial cross-sectional view showing a gas refrigerant separator-cum-refrigerant flow divider according to another modification of the invention; and

Fig. 38 is an axial cross-sectional view showing a gas refrigerant separatar-cum-refrigerant flow divider according to another modification of the invention.

MODES FOR CARRYING OUT THE INVENTION

(Embodiment 1)

[0048] A gas refrigerant separator according to a first embodiment of the present invention will now be described with reference to Figs. 1 to 4.

[0049] The gas refrigerant separator SG is connected to a passage at the outlet side of an expansion valve. As shown in Fig. 1(a), an inlet chamber 10, a speed increasing chamber 20, and an outlet chamber 30 are coaxially joined together and arranged in series. A refrigerant inlet pipe 11 and a gas refrigerant extracting pipe Pg are connected to the inlet chamber 10. A refrigerant outlet pipe 31 is connected to the outlet chamber 30. The gas refrigerant separator SG has a basic configuration for extracting separated gas refrigerant from the inlet chamber 10.

[0050] The inlet chamber 10 is cylindrical and has a side wall 12 located at the side opposite to the speed increasing chamber 20. A refrigerant inlet port 14 is formed in an inner wall surface of a peripheral wall 13 to introduce a two-phase gas-liquid flow from the expansion valve and guide the flow along the inner wall surface. The introduced refrigerant is thus caused to swirl along the inner wall surface (as indicated by the arrows in Figs. 2). The refrigerant inlet pipe 11 is connected to the refrigerant inlet port 14. The gas refrigerant extracting pipe Pg is connected to a central portion of the side wall 12. This configuration causes refrigerant to swirl along the inner wall surface of the peripheral wall 13. Gas refrigerant is gathered at the central portion and extracted through the gas refrigerant extracting pipe Pg.

[0051] The speed increasing chamber 20 has a conical shape having a diameter decreasing from the side corresponding to the inlet chamber 10 to the side corresponding to the outlet chamber 30. The diameter of the speed increasing chamber 20 at the inlet side is equal to the diameter of the inlet chamber 10. A communication port 21, the diameter of which is not significantly small, is formed at the distal end of the speed increasing chamber 20. The speed increasing chamber 20 communicates with the outlet chamber 30 through the communication port 21.

[0052] The outlet chamber 30 has a cylindrical shape having a diameter greater than the diameter of the communication port 21. In other words, the outlet chamber 30 has a comparatively great diameter. The outlet chamber 30 has a side wall 32, which is located at the side opposite to the inlet chamber 10. A refrigerant outlet pipe 31 is connected to a central portion of the side wall 32 to introduce liquid-rich refrigerant, which has been generated through gas refrigerant extraction, to the exterior (see Figs. 1).

[0053] The gas refrigerant separator SG, which is configured as described above, separates gas refrigerant from refrigerant in a two-phase gas-liquid state in the manner described below. First, as illustrated in Figs. 2, a two-phase gas-liquid flow is introduced into the cylindrical inlet chamber 10 along the inner wall surface of the peripheral wall 13 at a speed sufficiently great for swirling the refrigerant in the inlet chamber 10 without being influenced by gravity. This centrifugally collects liquid refrigerant substantially onto the inner wall surface of the peripheral wall 13. Gas refrigerant gathers to a middle portion of the swirling flow. The swirling flow, which is produced in the inlet chamber 10, is stabilized and maintained in a desirable state if the center of the swirling flow coincides with the center line of the gas refrigerant separator SG, which extends through the speed increasing chamber 20 and the outlet chamber 30. Specifically, at an early stage, the center of the swirling refrigerant flow in the inlet chamber 10 does not always coincide with the center of the gas refrigerant separator SG. However, as the speed of the swirling flow becomes greater in the speed increasing chamber, gas-liquid separation becomes more pronounced between the vicinity of the inner wall surface of the peripheral wall and the central portion. Correspondingly, the center of the swirling refrigerant flow gradually approaches the state coinciding with the center of the outlet chamber 30, thus homogenizing a liquid membrane.

[0054] The arrows in Figs. 2 illustrate a flow path of refrigerant. The broken arrow indicates the flow direction of the gas refrigerant that is directed out through the gas refrigerant extracting pipe Pg. The arrows in the drawings illustrating a gas refrigerant separator, a gas separator-cum-refrigerant flow divider, or an expansion valve for the embodiments that will be described later indicate refrigerant flows in similar manners.

[0055] The speed increasing chamber 20 has a distally tapered conical shape. The swirling diameter of the swirling refrigerant flow passing through the speed increasing chamber 20 becomes smaller toward the outlet port of the speed increasing chamber 20, thus increasing the swirling speed of the refrigerant. This also stabilizes the swirling refrigerant flow in the speed increasing chamber 20. Particularly, even when an intermittently changing two-phase gas-liquid flow is introduced through the refrigerant inlet port 14, uneven density distribution in the flow is canceled. Also, since the swirling diameter of the refrigerant is decreased toward the communication port 21, the center of the swirling refrigerant flow becomes approximate to the center axis of the speed increasing chamber 20. Further, once the swirling refrigerant flow is stabilized, the refrigerant density in the speed increasing chamber 20 is distributed in accordance with circular contour lines about the center of the speed increasing chamber 20. Accordingly, the conical shape of the speed increasing chamber 20 both increases the refrigerant swirling speed and stabilizes the refrigerant density distribution. This makes it unnecessary to employ any particular device to increase the refrigerant swirling speed or stabilize the refrigerant density distribution. The configuration of the gas refrigerant separator SG is thus simplified.

[0056] When refrigerant flows from the inlet chamber 10 into the speed increasing chamber 20, gas refrigerant is extracted through the inlet chamber 10, thus decreasing the proportion of the gas refrigerant contained in the refrigerant. This facilitates homogenization of the liquid membrane, stabilizing gas-liquid distribution in the speed increasing chamber 20 and ensuring a stable swirling refrigerant flow in the inlet chamber 10 and the speed increasing chamber 20. Afterwards, the refrigerant is sent from the speed increasing chamber 20 to the outlet chamber 30 having the comparatively small diameter through the communication port 21, which is arranged at the distal end of the speed increasing chamber 20.

[0057] After a refrigerant jet flow is delivered from the speed increasing chamber 20 to the outlet chamber 30 through the communication port 21, the diameter of which is not significantly small, liquid refrigerant is struck against the inner wall surface of the peripheral wall 33 by the centrifugal force produced by the swirling flow and gas refrigerant is blasted from the central portion. This forms a liquid containing swirling refrigerant flow along the inner wall surface of the peripheral wall 33 in the outlet chamber 30, thus stabilizing the swirling flow in the inlet chamber 10 and the speed increasing chamber 20. Further, once the gas refrigerant starts to be drawn into the gas refrigerant extracting pipe Pg in the inlet chamber, quick movement of the gas refrigerant further promotes gathering of the gas refrigerant to the center, thus stabilizing the swirling refrigerant flow. The gas refrigerant is thus stably extracted from the middle portion of the inlet chamber 10. On the other hand, liquid-rich refrigerant is sent to the exterior through the refrigerant outlet pipe 31, which is formed at the central portion of the side wall 32 of the outlet chamber 30.

[0058] Fig. 4 shows basic configurations possibly employed for the outlet chamber 30. The shape of the outlet chamber 30 corresponds to the basic configuration III in

Fig. 4. The other basic configurations will be referred to in relation to other embodiments, which will be described later.

[0059] An example of a refrigerating apparatus using the gas refrigerant separator, which is configured as described above, will hereafter be described with reference to the refrigerant circuit illustrated in Fig. 3.

[0060] The refrigerant circuit is a refrigerant circuit for a heat pump type air conditioner. The refrigerant circuit is an example having a heating gas refrigerant separator and a cooling gas refrigerant separator that are connected together. In the diagram of the refrigerant circuit in Fig. 3, the solid arrows indicate the refrigerant flow direction for cooling and the broken arrows indicate the refrigerant flow direction for heating. The arrows will be employed in similar manners herein for the diagrams of a refrigerant circuit that will be described later.

[0061] Specifically, a four-way switch valve 2 is connected to an outlet port and an inlet port of a compressor 1. Between switch ports 2a, 2b of the four-way switch valve 2, an outdoor heat exchanger 3, a heating refrigerant flow divider 4A, a heating gas refrigerant separator SG, an electric heating expansion valve 5A, an electric cooling expansion valve 5B, a cooling gas refrigerant separator SG, a cooling refrigerant flow divider 4B, and an indoor heat exchanger 6 are sequentially arranged. A bypass circuit 7A for bypassing the outdoor heat exchanger 3, which operates as a heating evaporator, connects the gas refrigerant extracting pipe Pg of the heating gas refrigerant separator SG to a point between the outdoor heat exchanger 3 and the four-way switch valve 2, which serves as the outlet side of the heating evaporator. A check valve 8A is arranged in the bypass circuit 7A to prevent bypassing from the point between the outdoor heat exchanger 3 and the four-way switch valve 2 to the gas refrigerant extracting pipe Pg at the time of cooling. Similarly, a bypass circuit 7B for bypassing the indoor heat exchanger 6, which operates as a cooling evaporator, connects the gas refrigerant extracting pipe Pg of the cooling gas refrigerant separator SG to a point between the outdoor heat exchanger 3 and the four-way switch valve 2, which serves as the outlet side of the cooling evaporator. A check valve 8B is arranged in the bypass circuit 7B to prevent bypassing from the point between the indoor heat exchanger 6 and the four-way switch valve 2 to the corresponding gas refrigerant extracting pipe Pg at the time of heating.

[0062] When cooling is performed by the air conditioner, which is configured as described above, the gas discharged from the compressor 1 is condensed by the outdoor heat exchanger 3 and sent to the cooling expansion valve 5B via the heating refrigerant flow divider 4A, the heating gas refrigerant separator SG, and the heating expansion valve 5A. The gas is then depressurized and expanded by the cooling expansion valve 5B to form a two-phase gas-liquid flow, which is introduced into the cooling gas refrigerant separator SG. The gas refrigerant separator SG extracts gas refrigerant from the refrigerant through the above-described operation and directs the gas refrigerant to the outlet side of the indoor heat exchanger 6, which operates as the evaporator, through the bypass circuit 7B. After the gas refrigerant is extracted by the cooling gas refrigerant separator, the remaining liquid-rich refrigerant is divided into multiple flow paths by the cooling refrigerant flow divider 4B and directed to a plurality of refrigerant passages, which are formed in the indoor heat exchanger 6. In the refrigerant passages, the liquid-rich refrigerant cools the indoor air and thus evaporates as gas refrigerant. The gas refrigerant is then merged with the gas refrigerant discharged from the gas refrigerant separator SG and returns to the compressor 1. Specifically, refrigerant proceeds through the heating refrigerant flow divider 4Aand the heating gas refrigerant separator SG in the opposite direction to the direction for heating. Accordingly, the heating refrigerant flow divider 4A and the heating gas refrigerant separator SG function simply as refrigerant passages.

[0063] When heating is performed, the gas discharged from the compressor 1 heats the indoor air in the indoor heat exchanger 6 and is thus condensed and sent to the heating expansion valve 5A via the cooling refrigerant flow divider 4B, the cooling gas refrigerant separator SG, and the cooling expansion valve 5B. The gas is then depressurized and expanded by the heating expansion valve 5A to form a two-phase gas-liquid flow, which is introduced into the heating gas refrigerant separator SG. The gas refrigerant separator SG extracts gas refrigerant from the refrigerant through the above-described operation and directs the gas refrigerant to the outlet side of the outdoor heat exchanger 3, which operates as the evaporator, through the bypass circuit 7A. After the gas refrigerant is extracted by the heating gas refrigerant separator SG, the remaining liquid-rich refrigerant is divided into multiple flow paths by the heating refrigerant flow divider 4A and directed to a plurality of refrigerant passages, which are formed in the outdoor heat exchanger 3. In the refrigerant passages, the liquid-rich refrigerant is subjected to heat exchange with the outdoor air and heated, thus evaporating as gas refrigerant. The gas refrigerant is then merged with the gas refrigerant sent from the gas refrigerant separator SG and returns to the compressor 1. Specifically, refrigerant proceeds through the cooling refrigerant flow divider 4B and the cooling gas refrigerant separator SG in the opposite direction to the direction for cooling. Accordingly, the cooling refrigerant flow divider 4B and the cooling gas refrigerant separator SG function simply as refrigerant passages.

[0064] Since the refrigerating apparatus employs the gas refrigerant separators SG, the refrigerating apparatus operates in the manner described below.

[0065] By the time refrigerant reaches the refrigerant flow dividers 4A, 4B, the amount of gas refrigerant contained in the refrigerant has been greatly decreased. This ensures a significant effect in preventing uneven flow distribution to the flow dividing pipes Pd. Also, the liquid-rich refrigerant, which has been generated through gas refrigerant extraction, flows into the heat exchanger serving as the evaporator (the outdoor heat exchanger 3 or the indoor heat exchanger 6), thus improving the surface heat transmission coefficient in the heat exchanger. Further, as the gas refrigerant decreases, the flow resistance of the refrigerant decreases. Additionally, the refrigerant that has evaporated in the refrigerant passages of the evaporator is merged with the refrigerant sent from the gas refrigerant separator SG and returns to the compressor 1. Accordingly, by adjusting the amount of the refrigerant sent from the gas refrigerant separator SG, the degree of superheating of the merged refrigerant may be set to an appropriate value. The degree of superheating of the refrigerant sent from the evaporator thus may be decreased. This allows the outdoor heat exchanger 3 and the indoor heat exchanger 6, each of which operates as the evaporator, to greatly enhance heat exchange efficiency.

[0066] The gas refrigerant separator and the refrigerating apparatus of the first embodiment, which are configured as described above, have the advantages described below.

(1) The gas refrigerant separator SG is configured by the inlet chamber 10, the speed increasing chamber 20, and the outlet chamber 30. This configuration stabilizes a swirling refrigerant flow in the inlet chamber 10 to prevent the flow from being influenced by gravity. As a result, the gas refrigerant separator SG is mounted in a refrigerating apparatus without strict accuracy required for the mounting direction thereof. Handling of the gas refrigerant separator SG is thus facilitated.

(2) Simply by forming the speed increasing chamber in a conical shape, the refrigerant swirling speed is increased and stabilized. This decreases the need for strict accuracy for the mounting direction and ensures further stable extraction of gas refrigerant. Further, even if an intermittently changing two-phase gas-liquid flow is sent from the refrigerant inlet port 14, uneven density distribution of the flow is canceled. This decreases noise caused by the refrigerant flow in, for example, the expansion valve.

(3) By incorporating the gas refrigerant separator SG in a refrigerant circuit, the amount of refrigerant gas in the refrigerant directed to the evaporator is decreased. This facilitates uniform flow distribution by the refrigerant flow divider 4A, 4B and improves the surface heat transmission coefficient in the evaporator, thus enhancing heat exchange efficiency in the evaporator.

(4) Since gas refrigerant is extracted from the inlet chamber 10, the proportion of gas refrigerant in the refrigerant sent to the speed increasing chamber 20 is decreased. This stabilizes gas-liquid distribution in the speed increasing chamber 20. As a result, a swirling refrigerant flow is stabilized in the inlet chamber 10 and the speed increasing chamber 20.

(Second Embodiment)

[0067] A gas refrigerant separator according to a second embodiment of the present invention will now be described with reference to Figs. 5 to 7.

[0068] Unlike the first embodiment, the description of the gas refrigerant separator SG of the second embodiment is focused on the basic configuration for extracting and separating gas refrigerant from the outlet chamber 30.

[0069] As in the case of the first embodiment, the gas refrigerant separator SG is connected to the outlet side of the expansion valve. With reference to Fig. 2(a), the inlet chamber 10, the speed increasing chamber 20, and the outlet chamber 30 are coaxially connected together and arranged in series. The refrigerant inlet pipe 11 is connected to the inlet chamber 10. The refrigerant outlet pipe 31 and the gas refrigerant extracting pipe Pg are connected to the outlet chamber 30.

[0070] As in the case of the first embodiment, the inlet chamber 10 is shaped cylindrically and has a side wall 12, which is formed at the side opposite to the speed increasing chamber 20. The refrigerant inlet port 14 is formed in the inner wall surface of the peripheral wall 13 to introduce a two-phase gas-liquid flow from an expansion valve and guide the flow along the inner wall surface of the peripheral wall 13. The introduced refrigerant swirls along the inner wall surface (as indicated by the arrows in Figs. 6). The refrigerant inlet pipe 11 is connected to the refrigerant inlet port 14.

[0071] Like the first embodiment, the speed increasing chamber 20 has a conical shape the diameter of which decreases from the side corresponding to the inlet chamber 10 to the side corresponding to the outlet chamber 30. The diameter of the speed increasing chamber 20 at the inlet side is equal to the diameter of the inlet chamber 10. The communication port 21, the diameter of which is not significantly small, is formed at the distal end of the speed increasing chamber 20. The speed increasing chamber 20 communicates with the outlet chamber 30 through the communication port 21. The dimension of the communication port 21 of the second embodiment is substantially equal to the dimension of the communication port 21 of the first embodiment.

[0072] The outlet chamber 30 has a cylindrical shape having a diameter that is greater than the diameter of the communication port 21, or, in other words, a comparatively great diameter. However, the inner diameter of the outlet chamber 30 is smaller than the inner diameter of the inlet chamber 10 such that refrigerant swirls in the outlet chamber 30. The side surface of the outlet chamber 30 at the side opposite to the inlet chamber 10 is shaped to be continuously joined to the refrigerant outlet pipe 31. The refrigerant outlet pipe 31 thus has such a large diameter portion that the refrigerant outlet pipe 31 is smoothly joined to the outlet chamber 30. The gas refrigerant extracting pipe Pg is arranged like an inner pipe of a double pipe structure in which the refrigerant outlet pipe

31 serves as an outer pipe. The gas refrigerant extracting pipe Pg is supported at the portion of the gas refrigerant extracting pipe Pg extending through the refrigerant outlet pipe 31. The gas refrigerant extracting pipe Pg thus extracts gas refrigerant that has been collected to a central portion of a swirling refrigerant flow in the outlet chamber 30. The refrigerant outlet pipe 31 is configured to direct the liquid-rich refrigerant that swirls around the gas refrigerant extracting pipe Pg to the exterior.

[0073] In the gas refrigerant separator SG, which is configured as described above, a two-phase gas-liquid flow of refrigerant is introduced from the refrigerant inlet port 14, guided along the inner wall surface of the peripheral wall 13, and caused to swirl with such an intensity in the inlet chamber 10 that the refrigerant is not influenced by gravity, as in the case of the first embodiment. Liquid refrigerant is thus centrifugally gathered substantially along the inner wall surface of the peripheral wall 13 and gas refrigerant is collected to the middle portion of the swirling flow. The speed of the swirling flow, which is produced in the inlet chamber 10, is increased in the speed increasing chamber 20 through the same operation as the operation of the first embodiment. The center of the swirling flow is thus stabilized.

[0074] The refrigerant in the speed increasing chamber 20 passes through the communication port 21, the size of which is not significantly small, formed at the distal end of the speed increasing chamber 20, and flows into the outlet chamber 30 having the comparatively great diameter. After a refrigerant jet flow is discharged from the speed increasing chamber 20 to the outlet chamber 30 through the communication port 21, the diameter of which is not significantly small, liquid refrigerant strikes against the inner wall surface of the peripheral wall 33 by the centrifugal force produced by the swirling flow and gas refrigerant is blasted from the central portion. As a result, liquid containing refrigerant swirls along the inner wall surface of the peripheral wall 33 in the outlet chamber 30. This forms a swirling refrigerant flow having a center coinciding with the center of the outlet chamber 30. Further, gas refrigerant is extracted from the middle portion of the outlet chamber 30 through the gas refrigerant extracting pipe Pg, which has an opening facing the central portion of the outlet chamber 30. This forms a stable flow of gas refrigerant extending along the center axis from the middle of the communication port 21 to the gas refrigerant extracting pipe Pg. In this manner, the swirling refrigerant flow in the outlet chamber 30 is stabilized and the gas refrigerant is extracted stably. The shape of the outlet chamber 30 of the second embodiment corresponds to the basic configuration III illustrated in Fig. 4.

[0075] An example of a refrigerating apparatus employing the gas refrigerant separator SG, which is configured in the above-described manner, will now be described with reference to the refrigerant circuit illustrated in Fig. 7.

[0076] The refrigerant circuit is similar to the refrigerant circuit for the heat pump type air conditioner illustrated in Fig. 3. Simply, the gas refrigerant separators SG of the first embodiment are replaced by the gas refrigerant separators SG of the second embodiment. The configuration and operation of the refrigerant circuit of the second embodiment is the same as the configuration and operation of the refrigerant circuit of the first embodiment.

[0077] The gas refrigerant separator of the second embodiment and the refrigerating apparatus employing the gas refrigerant separator, which are configured as described above, have the advantages described below in addition to the same advantages as the advantages (1) to (3) of the first embodiment.

(5) In the outlet chamber 30, the gas refrigerant extracting pipe Pg, which has an opening facing the central portion of the outlet chamber 30, extracts gas refrigerant from the middle portion of the outlet chamber 30. This forms a stable flow of gas refrigerant extending along the center axis from the middle of the communication port 21 to the gas refrigerant extracting pipe Pg. The gas refrigerant is thus stably extracted.

(6) The refrigerant outlet pipe 31 and the gas refrigerant extracting pipe Pg, which are connected to the outlet chamber 30, are formed as the double pipe structure, thus simplifying the configuration.

(Third Embodiment)

[0078] A gas refrigerant separator-cum-refrigerant flow divider according to a third embodiment of the present invention will now be described with reference to Figs. 8 and 9.

[0079] The third embodiment relates to a gas refrigerant separator-cum-refrigerant flow divider employing the gas-liquid separating mechanism of the above-described gas refrigerant separators and a refrigerating apparatus using the gas refrigerant separator-cum-refrigerant flow divider.

[0080] Compared to the first embodiment, the diameter of the outlet chamber 30 is slightly small in the gas refrigerant separator-cum-refrigerant flow divider DR of the third embodiment. Also, the refrigerant outlet pipe 31 of the first embodiment is modified to form a plurality of flow dividing pipes Pd, which are connected to corresponding refrigerant passages formed in an evaporator. In other words, the inlet chamber 10 and the speed increasing chamber 20 of the third embodiment are identical to those of the first embodiment but the outlet chamber 30 of the third embodiment is configured differently from that of the first embodiment.

[0081] The outlet chamber 30 has a cylindrical shape and the diameter of the outlet chamber 30 is comparatively small (small compared to the diameter of the outlet chamber 30 of the first embodiment).

[0082] In the third embodiment, the gas refrigerant separator-cum-refrigerant flow divider DR employs a plurality of (in this embodiment, three) flow dividing pipes

Pd, which are connected to corresponding refrigerant passages in an evaporator, as the refrigerant outlet pipe 31 of the gas refrigerant separator SG of the first embodiment. The flow dividing pipes Pd are spaced apart at equal intervals along a certain circumference. The radius r1 of the circle connecting the corresponding points on the inner surfaces of the three flow dividing pipes Pd is greater than the radius r2 of the communication port 21. This prevents the refrigerant introduced from the communication port 21 from being drawn directly into the flow dividing pipes Pd and allows the flow dividing pipes Pd to draw refrigerant from the vicinity of the peripheral wall 33, onto which liquid refrigerant is gathered.

[0083] A swirling refrigerant flow operates in the inlet chamber 10 and the speed increasing chamber 20 of the gas refrigerant separator-cum-refrigerant flow divider DR in the same manner as the swirling refrigerant flow in the first embodiment. Since gas refrigerant is extracted from the inlet chamber 10, the proportion of gas refrigerant in the refrigerant flowing into the speed increasing chamber 20 is decreased. This facilitates homogenization of a liquid membrane, thus stabilizing gas-liquid distribution in the speed increasing chamber 20. As a result, the swirling refrigerant flow in the inlet chamber 10 and the speed increasing chamber 20 is stabilized and gas refrigerant is stably extracted from the inlet chamber 10.

[0084] After a refrigerant flow is jetted from the speed increasing chamber 20 to the outlet chamber 30 through the communication port 21, the diameter of which is not significantly small, liquid refrigerant strikes against the inner wall surface of the peripheral wall 33 by the centrifugal force produced by the swirling flow and gas refrigerant is blasted from the center portion. As a result, in the outlet chamber 30, the refrigerant strikes against the inner wall surface of the peripheral wall 33 hitting the inner wall surface of the peripheral wall 33 and is thus stirred. The refrigerant forms an axisymmetric flow that proceeds from the inner wall surface of the peripheral wall 33 toward the center of the outlet chamber 30. This stabilizes the swirling flow in the inlet chamber 10 and the speed increasing chamber 20. Further, once gas refrigerant starts to be drawn into the gas refrigerant extracting pipe Pg in the inlet chamber 10, quick movement of the refrigerant gas further promotes gathering of the gas refrigerant at the center, thus stabilizing the swirling refrigerant flow. The gas refrigerant is thus stably extracted from the middle portion of the inlet chamber 10.

[0085] The gas-liquid distribution and the refrigerant flow path in the outlet chamber 30 are basically the same as those for the basic configuration II (see Fig. 4). However, the outlet chamber 30 functions also as a flow divider.

[0086] By the time refrigerant is drawn from the outlet chamber 30 into the flow dividing pipes Pd, gas refrigerant has been extracted through the gas refrigerant extracting pipe Pg to decrease the proportion of the gas refrigerant in the refrigerant. The flow dividing pipes Pd each have an opening facing the axisymmetric portion of the refrigerant flow, which proceeds from the inner wall surface of the peripheral wall 33 toward the center of the outlet chamber 30. The refrigerant is thus divided into uniform flows. The swirling refrigerant flow formed in this manner cancels influence by the mounting direction of the gas refrigerant separator-cum-refrigerant flow divider DR in a refrigerating apparatus.

[0087] Fig. 9 represents the refrigerant circuit in the refrigerating apparatus incorporating the gas refrigerant separator-cum-refrigerant flow divider, which is configured in the above-described, manner. In the refrigerant circuit of the first embodiment represented in Fig. 3, the gas refrigerant separator SG and the cooling refrigerant flow divider 4B are arranged between the cooling expansion valve 5B and the indoor heat exchanger 6 and the gas refrigerant separator SG and the heating refrigerant flow divider 4A are located between the heating expansion valve 5A and the outdoor heat exchanger 3. However, in the refrigerant circuit of the third embodiment, as illustrated in Fig. 9, simply by arranging the gas refrigerant separator-cum-refrigerant flow dividers DR between the cooling expansion valve 5B and the indoor heat exchanger 6 and between the heating expansion valve 5A and the outdoor heat exchanger 3, the same advantages as the advantages of the first embodiment are brought about.

[0088] The gas refrigerant separator-cum-refrigerant flow divider of the third embodiment, which is configured as described above, has the advantages (7) to (10) similar to the advantages (1) to (4) of the first embodiment, as will be described. The third embodiment also has the advantage (11) in addition to the advantages (7) to (10).

(7) The gas refrigerant separatar-cum-refrigerant flow divider DR of the third embodiment is configured by the inlet chamber 10, the speed increasing chamber 20, and the outlet chamber 30. This configuration stabilizes a swirling refrigerant flow in the inlet chamber 10 to prevent the swirling flow from being influenced by gravity. As a result, the gas refrigerant separator-cum-refrigerant flow divider DR is mounted in the refrigerating apparatus without strict accuracy in its mounting direction. Handling of the gas refrigerant separator-cum-refrigerant flow divider DR is thus facilitated.

(8) Simply by forming the speed increasing chamber 20 in a conical shape, the refrigerant swirling speed is increased and stabilized. This relaxes strict accuracy in the mounting direction and ensures further stable extraction of gas refrigerant. Further, even if an intermittently changing two-phase gas-liquid flow is sent from the refrigerant inlet port 14, uneven density distribution of the flow is canceled. This decreases noise caused by the refrigerant flow in, for example, the expansion valve.

(9) By incorporating the gas refrigerant separator-cum-refrigerant flow divider DR in the refrigerant circuit, the amount of refrigerant gas in the refrigerant

sent to the evaporator is decreased. This facilitates uniform flow distribution to the flow dividing pipes Pd and improves the surface heat transmission coefficient in the evaporator, thus enhancing the heat exchange efficiency of the evaporator.

(10) Since gas refrigerant is extracted from the inlet chamber 10, the proportion of gas refrigerant in the refrigerant sent to the speed increasing chamber 20 is decreased. This stabilizes gas-liquid distribution in the speed increasing chamber 20. As a result, a swirling refrigerant flow is stabilized in the inlet chamber 10 and the speed increasing chamber 20.

(11) The gas refrigerant separator-cum-refrigerant flow divider DR functions integrally as a gas refrigerant separator and a refrigerant flow divider. This makes it unnecessary to employ a separately manufactured gas refrigerant separator or refrigerant flow divider. The number of the parts control steps and the number of the parts mounting steps are thus decreased.

(Fourth Embodiment)

[0089] A gas refrigerant separator-cum-refrigerant flow divider according to a fourth embodiment of the present invention and a refrigerating apparatus using the gas refrigerant separator-cum-refrigerant flow divider will now be described with reference to Figs. 10 and 11.

[0090] As illustrated in Figs. 10, the gas refrigerant separator-cum-refrigerant flow divider DR of the fourth embodiment is different from the third embodiment in that the outlet chamber 30 of the fourth embodiment has a greater diameter and that gas refrigerant is extracted from the outlet chamber 30. Further, the fourth embodiment employs the flow dividing pipes Pd of the third embodiment to replace the refrigerant outlet pipe 31 of the first embodiment. The flow dividing pipes Pd extend from the side wall 32 of the outlet chamber 30 opposing the communication port 21.

[0091] In other words, the inlet chamber 10 and the speed increasing chamber 20 of the gas refrigerant separator-cum-refrigerant flow divider DR of the fourth embodiment is different from those of the third embodiment in that the gas refrigerant extracting pipe Pg of the fourth embodiment is not connected to the inlet chamber 10. However, the other components of the inlet chamber 10 and the speed increasing chamber 20 of the fourth embodiment are identical to those of the third embodiment.

[0092] The diameter of the outlet chamber 30 of the fourth embodiment is greater than the diameter of the outlet chamber 30 of the third embodiment. That is, the outlet chamber 30 of the fourth embodiment has a moderate diameter. Also, like the third embodiment, the three flow dividing pipes Pd are spaced apart at equal intervals along a certain circumference to draw refrigerant from the vicinity of the peripheral wall 33. The gas refrigerant extracting pipe Pg is connected to the central portion of the side wall 32 of the outlet chamber 30. To cause refrigerant in the outlet chamber 30 to swirl, the radius of the outlet chamber 30 is set smaller than the radius of the inlet chamber 10 according to the law of conservation of angular momentum.

[0093] The gas refrigerant separator-cum-refrigerant flow divider DR, which is configured as described above, introduces a two-phase gas-liquid flow of refrigerant from the refrigerant inlet port 14, guides the flow along the inner wall surface of the peripheral wall 13, and swirls the flow in the inlet chamber 10 with such intensity that the flow is not influenced by gravity. Liquid refrigerant is thus centrifugally collected substantially onto the inner wall surface of the peripheral wall 13 and gas refrigerant only is gathered at the middle portion of the swirling flow. The speed of the swirling flow, which is produced in the inlet chamber 10, is increased in the speed increasing chamber 20 through the same operation as the operation of each of the first to third embodiments. This stabilizes the center of the swirling flow.

[0094] The refrigerant in the speed increasing chamber 20 passes through the communication port 21, which is not significantly small and formed at the distal end of the speed increasing chamber 20, and flows into the outlet chamber 30 having the comparatively great diameter. After the refrigerant jet flow is sent from the speed increasing chamber 20 to the outlet chamber 30 through the communication port 21, the diameter of which is not significantly small, liquid refrigerant is struck against the inner wall surface of the peripheral wall 33 by the centrifugal force produced by the swirling flow and gas refrigerant is blasted from the center portion. As a result, liquid containing refrigerant swirls along the inner wall surface of the peripheral wall 33 in the outlet chamber 30. This forms a swirling refrigerant flow having a center coinciding with the center of the outlet chamber 30. Further, gas refrigerant is extracted from the middle portion of the outlet chamber 30 through the gas refrigerant extracting pipe Pg, which has an opening facing the central portion of the outlet chamber 30. This forms a stable flow of gas refrigerant extending along the center axis from the middle of the communication port 21 to the gas refrigerant extracting pipe Pg. In this manner, the swirling refrigerant flow in the outlet chamber 30 is stabilized and the gas refrigerant is stably extracted. The shape of the outlet chamber 30 of the fourth embodiment corresponds to the basic configuration III illustrated in Fig. 4.

[0095] The flow dividing pipes Pd of the outlet chamber 30 each have an opening facing a swirling flow of liquid-rich refrigerant swirling along the inner wall surface of the peripheral wall 33. The refrigerant is thus divided into uniform flows. Further, since the flow division is carried out on the swirling flow of liquid-rich refrigerant, the gas refrigerant separator-cum-refrigerant flow divider DR is mounted in a refrigerating apparatus without being influenced by the mounting direction.

[0096] The refrigerating apparatus incorporating the gas refrigerant separator-cum-refrigerant flow divider DR is configured basically identical to the refrigerating apparatus of the third embodiment except for the extracting position of the gas refrigerant extracting pipe Pg with respect to the gas refrigerant separator-cum-refrigerant flow divider DR.

[0097] The fourth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and (11) of the third embodiment. The fourth embodiment also has the advantage described below.

(12) A stable flow of gas refrigerant is formed along the center axis from the middle of the communication port 21 to the gas refrigerant extracting pipe Pg. This stabilizes the swirling refrigerant flow in the outlet chamber 30, thus stabilizing gas refrigerant extraction and improving flow division performance.

(Fifth Embodiment)

[0098] A gas refrigerant separator-cum-refrigerant flow divider according to a fifth embodiment of the present invention and a refrigerating apparatus using the gas refrigerant separator-cum-refrigerant flow divider will now be described with reference to Figs. 12.

[0099] The outlet chamber 30 of the gas refrigerant separator-cum-refrigerant flow divider DR of the fifth embodiment is modified as illustrated in Fig. 12. The other components of the fifth embodiment are configured identical to the corresponding components of the fourth embodiment. Specifically, the outlet chamber 30 of the fifth embodiment has a conical shape that gradually enlarges from the communication port 21 of the speed increasing chamber 20. The communication port 21 of the fifth embodiment is sized equal to the communication port 21 of the fourth embodiment. The maximum diameter of the outlet chamber 30 of the fifth embodiment is substantially equal to or slightly greater than that of the fourth embodiment.

[0100] In this configuration, refrigerant flows in the inlet chamber 10 and the speed increasing chamber 20 substantially in the same manner as the fourth embodiment. However, in the outlet chamber 30, the refrigerant flows as will be described. After a refrigerant jet flow is sent from the speed increasing chamber 20 to the outlet chamber 30, liquid refrigerant is centrifugally moved along the peripheral wall 33, which extends conically. Gas refrigerant is blasted from the middle portion. A liquid membrane is formed along the inner wall surface of the peripheral wall 33 in the outlet chamber 30 and only the gas refrigerant is gathered to the middle portion of the outlet chamber 30. As a result, in this case, gas-liquid separation in the outlet chamber 30 is carried out with improved reliability. This stabilizes gas refrigerant extraction from the outlet chamber 30. Also in the fifth embodiment, the gas refrigerant extracting pipe Pg is connected to the central portion of the side wall 32 of the outlet chamber 30, as in the fourth embodiment. This forms a stable flow of gas refrigerant along the center axis from the middle of the communication port 21 to the gas refrigerant extracting pipe Pg. As a result, the above-described operations produce a synergetic effect to further stabilize the swirling refrigerant flow in the outlet chamber 30. Correspondingly, this further stabilizes extraction of gas refrigerant and further improves refrigerant flow division performance. The shape of the outlet chamber 30 of the fifth embodiment corresponds to the basic configuration IV illustrated in Fig. 4.

[0101] The gas refrigerant separator-cum-refrigerant flow divider DR of the fifth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and

(11) of the third embodiment, like the fourth embodiment, and the same advantage as the advantage (12) of the fourth embodiment. The fifth embodiment also has the advantage described below.

(13) In the gas refrigerant separator-cum-refrigerant flow divider DR of the fifth embodiment, after a refrigerant jet flow is directed from the speed increasing chamber 20 to the outlet chamber 30, liquid refrigerant is centrifugally collected onto the peripheral wall 33 and gas refrigerant is blasted from the middle portion. This ensures stable swirling in the outlet chamber 30 and further improves gas refrigerant separation performance and refrigerant flow division performance.

(Sixth Embodiment)

[0102] A gas refrigerant separator-cum-refrigerant flow divider according to a sixth embodiment of the present invention will now be described with reference to Fig. 13.

[0103] As illustrated in Fig. 13, the gas refrigerant separator-cum-refrigerant flow divider DR of the sixth embodiment is modified from the third embodiment in that the communication port 21 and the cylindrical outlet chamber 30 both have a smaller diameter. As a result, a refrigerant circuit incorporating the gas refrigerant separator-cum-refrigerant flow divider DR is identical to the refrigerant circuit illustrated in Fig. 9.

[0104] In the sixth embodiment, refrigerant swirls in the inlet chamber 10 and the speed increasing chamber 20 substantially in the same manner as the third embodiment. However, since the communication port 21 of the sixth embodiment has the smaller diameter, a swirling flow for refrigerant is throttled by the communication port 21 when moving from the speed increasing chamber 20 into the outlet chamber 30. This produces a liquid-containing refrigerant flow that is jetted from the middle portion of the communication port 21. The flow thus strikes the side wall 32 facing the communication port 21 and then forms a flow swirling along the inner wall surface of the peripheral wall 33. As a result, the refrigerant flow in the outlet chamber 30 is uniform in gas-liquid distribution and axisymmetric with respect to the axis of the outlet chamber 30. This stabilizes the swirling flow in the inlet chamber 10 and the speed increasing chamber 20.

[0105] By the time the refrigerant flow reaches the outlet chamber 30, gas refrigerant has been extracted through the inlet chamber 10. The refrigerant is thus liquid-rich. Also, as has been described, the refrigerant flow uniform in gas-liquid distribution is formed axisymmetric with respect to the axis of the outlet chamber 30. As a result, the refrigerant flow is divided into uniform flows for the flow dividing pipes Pd. The shape of the outlet chamber 30 corresponds to the basic configuration I illustrated in Fig. 4. As a result, mounting of the gas refrigerant separator-cum-refrigerant flow divider DR of the sixth embodiment also does not require strict accuracy in the mounting direction.

[0106] The gas refrigerant separator-cum-refrigerant flow divider DR of the sixth embodiment, which has the above-described configuration, has the same advantages as the advantages (7) to (11) of the third embodiment.

(Seventh Embodiment)

[0107] A gas refrigerant separator-cum-refrigerant flow divider according to a seventh embodiment of the present invention will now be described with reference to Fig. 14.

[0108] The gas refrigerant separator-cum-refrigerant flow divider DR of the seventh embodiment is modified from the fourth embodiment in terms of the shape of the inlet chamber 10. The inlet chamber 10 of the seventh embodiment has a conical shape the diameter of which becomes greater toward the speed increasing chamber 20. The opening area of the inlet chamber 10 at the side corresponding to the speed increasing chamber 20 is equal to the opening area of the speed increasing chamber 20 at the side corresponding to the inlet chamber 10.

[0109] In this configuration, the peripheral wall 13 extends in a conical shape and thus guides refrigerant into the speed increasing chamber 20 after the refrigerant has been sent from the refrigerant inlet port 14 into the inlet chamber 10.

[0110] The gas refrigerant separator-cum-refrigerant flow divider DR of the seventh embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and (11) of the third embodiment, like the fourth embodiment, and the same advantage as the advantage (12) of the fourth embodiment. The seventh embodiment also has the advantage described below. (14) The refrigerant that has been introduced into the inlet chamber 10 through the refrigerant inlet port 14 is guided into the speed increasing chamber 20 by means of the peripheral wall 13 of the inlet chamber 10. This stabilizes a refrigerant jet flow into the outlet chamber 30 through the communication port 21 of the speed increasing chamber 20. As a result, gas refrigerant extraction is stabilized and refrigerant flow division performance is enhanced.

(Eighth Embodiment)

[0111] A gas refrigerant separator-cum-refrigerant flow divider according to an eighth embodiment of the present invention will now be described with reference to Fig. 15.

[0112] The gas refrigerant separator-cum-refrigerant flow divider DR of the eighth embodiment is modified from the fourth embodiment in terms of the shape of the inlet chamber 10, as in the seventh embodiment. However, the inlet chamber 10 of the eighth embodiment has an inclined cylindrical shape and is inclined in the direction in which an introduced refrigerant flow is guided into the speed increasing chamber 20. In other words, the inlet chamber 10 is shaped like a cylinder that extends along an inclined axis. The opening area of the inlet chamber 10 at the side corresponding to the speed increasing chamber 20 is equal to the opening area of the speed increasing chamber 20 at the side corresponding to the inlet chamber 10.

[0113] In this configuration, the peripheral wall 13 adds a flow component moving toward the speed increasing chamber 20 to the refrigerant that has been introduced into the inlet chamber 10 through the refrigerant inlet port 14. That is, the peripheral wall 13 of the inlet chamber 10 guides the refrigerant to the speed increasing chamber 20. As a result, the gas refrigerant separator-cum-refrigerant flow divider DR of the eighth embodiment has the same advantages as the advantages of the seventh embodiment. In other words, the eighth embodiment has the same advantages as the advantages (7) to (9) and (11) of the third embodiment, the same advantage as the advantage (12) of the fourth embodiment, and the same advantage as the advantage (14) of the seventh embodiment.

(Ninth Embodiment)

[0114] A gas refrigerant separator-cum-refrigerant flow divider according to a ninth embodiment of the present invention will now be described with reference to Fig. 16.

[0115] The gas refrigerant separator-cum-refrigerant flow divider DR of the ninth embodiment is modified from the fourth embodiment in that the ninth embodiment includes a flow adjusting portion 14a to add a swirling component to a refrigerant flow sent into the refrigerant inlet port 14 of the inlet chamber 10.

[0116] The flow adjusting portion 14a connects the refrigerant inlet pipe 11 to the refrigerant inlet port 14 such that the distance between the inner peripheral surface of the refrigerant inlet pipe 11 and the center of the inlet chamber 10 on a plane perpendicular to the axis of the refrigerant inlet pipe 11, which is the eccentric distance S, becomes greater than the corresponding distance in the fourth embodiment. The flow adjusting portion 14a of the ninth embodiment is configured by a straight pipe portion 14aa extending continuously from the refrigerant inlet pipe 11 and a joint portion 14ab, which joins the straight pipe portion 14aa to the refrigerant inlet port 14 in an inclined manner.

[0117] In this configuration, the increased eccentric distance S applies swirling force, in advance, to the refrigerant flowing into the inlet chamber 10. This increases the swirling force produced by the refrigerant in the inlet chamber 10.

[0118] The gas refrigerant separator-cum-refrigerant flow divider DR of the ninth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and (11) of the third embodiment, like the fourth embodiment, and the same advantage as the advantage (12) of the fourth embodiment. The ninth embodiment also has the advantage described below.

(15) The swirling force is applied to a refrigerant flow introduced into the inlet chamber 10 in advance, thus stabilizing a swirling flow in the inlet chamber 10. As a result, the center of the swirling flow in the inlet chamber 10 becomes approximate to the center of the outlet chamber 30. This stabilizes gas refrigerant extraction and improves refrigerant flow division performance.

(Tenth Embodiment)

[0119] A gas refrigerant separator-cum-refrigerant flow divider according to a tenth embodiment of the present invention will now be described with reference to Fig. 17.

[0120] Like the ninth embodiment, the gas refrigerant separator-cum-refrigerant flow divider DR of the tenth embodiment is modified from the fourth embodiment in that the tenth embodiment has the flow adjusting portion 14a, which applies a swirling component to a refrigerant flow introduced into the refrigerant inlet port 14 of the inlet chamber 10.

[0121] The flow adjusting portion 14a of the tenth embodiment increases the eccentric distance S as in the case of the ninth embodiment but with improvement from the ninth embodiment. Specifically, in the tenth embodiment, the joint portion 14ab is formed by a pipe angled at a right angle, not the inclined joint pipe of the ninth embodiment. At the distal end of the joint portion 14ab, the inner peripheral surface of the curved pipe is connected smoothly to the inner wall surface of the peripheral wall 13 of the inlet chamber 10.

[0122] In this configuration, the refrigerant flowing through the refrigerant inlet pipe 11 receives swirling force in advance, as in the ninth embodiment. Also, in the gas refrigerant separator-cum-refrigerant flow divider DR of the tenth embodiment, centrifugal force acts on refrigerant when the refrigerant passes through the joint portion 14ab, which is curved. As a result, liquid-rich refrigerant proceeds on a radially outer side in the curved portion of the joint portion 14ab and gas-rich refrigerant flows on a radially inner side in the curved portion of the joint portion 14ab. Accordingly, by the time refrigerant reaches the inlet chamber 10, the refrigerant has been transformed into a gas-liquid separated state. This stabilizes density distribution in the refrigerant introduced into the inlet chamber 10. As a result, gas refrigerant extraction is stabilized and refrigerant flow division performance is improved.

[0123] The gas refrigerant separator-cum-refrigerant flow divider DR of the tenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and (11) of the third embodiment, like the fourth embodiment, and the same advantage as the advantage (12) of the fourth embodiment. The tenth embodiment also has the advantage described below.

(16) The joint portion 14ab improves stability of the refrigerant flowing into the inlet chamber 10, thus stabilizing a swirling refrigerant flow in the inlet chamber 10. As a result, gas refrigerant extraction is stabilized and refrigerant flow division performance is improved.

(Eleventh Embodiment)

[0124] A gas refrigerant separator-cum-refrigerant flow divider according to an eleventh embodiment of the present invention will now be described with reference to Fig. 18.

[0125] Like the ninth and tenth embodiments, the gas refrigerant separator-cum-refrigerant flow divider DR of the eleventh embodiment is modified from the fourth embodiment in that the eleventh embodiment has the flow adjusting portion 14a, which applies a swirling component to a refrigerant flow introduced into the refrigerant inlet port 14 of the inlet chamber 10.

[0126] However, the flow adjusting portion 14a of the eleventh embodiment is slightly different from the tenth embodiment and configured by the straight pipe portion 14aa extending continuously from the refrigerant inlet pipe 11, the joint portion 14ab formed by a pipe angled at a right angle, and a large diameter portion 14ac, which extends inward from the joint portion 14ab. The distal end of the large diameter portion 14ac is located in the vicinity of the center of the inlet chamber 10.

[0127] In this configuration, swirling force is applied to the refrigerant flowing from the refrigerant inlet pipe 11 in advance, as in the tenth embodiment. The refrigerant also receives centrifugal force when passing through the curved joint portion 14ab so that liquid-rich refrigerant proceeds on a radially outer side in the joint portion 14ab and gas-rich refrigerant moves on a radially inner side in the joint portion 14ab. The eleventh embodiment also includes the large diameter portion 14ac, which extends to a position close to the center of the inlet chamber 10. This directs the gas-rich refrigerant to the vicinity of the center of the inlet chamber 10, thus making it easy for a swirling flow to have an axis coinciding with the center of the inlet chamber 10. In this manner, swirling flow about the center of the inlet chamber 10 is smoothly generated.

[0128] The gas refrigerant separator-cum-refrigerant flow divider DR of the eleventh embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and (11) of the fourth embodiment, like the third embodiment, and the same advantage as the advantage (12) of the fourth embodiment. The eleventh embodiment also has the advantage described below.

(17) Gas-rich refrigerant is smoothly introduced to the vicinity of the center of the inlet chamber 10 and forms a swirling flow substantially about the center of the inlet chamber 10. This stabilizes a swirling refrigerant flow in the inlet chamber 10, thus stabilizing gas refrigerant extraction and improving refrigerant flow division performance.

(Twelfth Embodiment)

[0129] A gas refrigerant separator-cum-refrigerant flow divider according to a twelfth embodiment of the present invention will now be described with reference to Fig. 19.

[0130] Like the ninth to eleventh embodiments, the gas refrigerant separator-cum-refrigerant flow divider DR of the twelfth embodiment is modified from the fourth embodiment that the twelfth embodiment has the flow adjusting portion 14a, which applies a swirling component to a refrigerant flow flowing into the refrigerant inlet port 14 of the inlet chamber 10.

[0131] However, the purpose of the flow adjusting portion 14a of the twelfth embodiment is not to increase the eccentric distance but to form a refrigerant flow smoothly along the inner Wall surface of the inlet chamber by means of a curved pipe. In other words, as in the case of the tenth embodiment, the flow adjusting portion 14a of the twelfth embodiment is configured by the straight pipe portion 14aa and the curved joint portion 14ab. However, the straight pipe portion 14aa and the joint portion 14ab are arranged in the cylindrical inlet chamber 10 in the twelfth embodiment. The inner peripheral surface of the joint portion 14ab is smoothly connected to the inner wall surface of the peripheral wall 13 of the inlet chamber 10.

[0132] This configuration applies centrifugal force to refrigerant when the refrigerant passes through the curved joint portion 14ab as in the tenth embodiment. As a result, liquid-rich refrigerant proceeds on a radially outer side in the joint portion 14ab and gas-rich refrigerant moves on a radially inner side in the joint portion 14ab. This stabilizes density distribution in the refrigerant flowing into the inlet chamber 10, thus ensuring a stable swirling flow in the inlet chamber 10.

[0133] The gas refrigerant separator-cum-refrigerant flow divider DR of the twelfth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and (11) of the third embodiment, like the fourth embodiment, and the same advantage as the advantage (12) of the fourth embodiment. The twelfth embodiment also has the same advantage as the advantage (15) of the ninth embodiment.

(Thirteenth Embodiment)

[0134] A gas refrigerant separator-cum-refrigerant flow divider according to a thirteenth embodiment of the present invention will now be described with reference to Fig. 20.

[0135] The gas refrigerant separator-cum-refrigerant flow divider DR of the thirteenth embodiment is modified from the sixth embodiment in the shape of the joint portion between the inlet chamber 10 and the speed increasing chamber 20. Specifically, in the thirteenth embodiment, as illustrated in Fig. 20, the diameter d1 of the inlet chamber 10 at the joint portion between the inlet chamber 10 and the speed increasing chamber 20 is greater than the diameter d2 of the speed increasing chamber 20 to form a step 16 at the joint portion.

[0136] In this configuration, after flowing from the inlet chamber 10, refrigerant is temporarily retained by the step 16 before being sent into the speed increasing chamber 20. This increases the amount of the swirling component in the refrigerant. Specifically, the step 16 restricts the flow component moving from the inlet chamber 70 to the speed increasing chamber 20 to increase the speed at which the refrigerant swirls in the inlet chamber 10. This intensifies the swirling component before the refrigerant reaches the speed increasing chamber 20.

[0137] The gas refrigerant separator-cum-refrigerant flow divider DR of the thirteenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (11) of the third embodiment, like the sixth embodiment. The thirteenth embodiment also has the advantage described below.

(18) The step 16 increases the amount of the swirling refrigerant component that is produced in the inlet chamber 10. This stabilizes a swirling refrigerant flow flowing into the speed increasing chamber 20. As a result, gas refrigerant extraction is stabilized and refrigerant flow division performance is improved.

(Fourteenth Embodiment)

[0138] A gas refrigerant separator-cum-refrigerant flow divider according to a fourteenth embodiment of the present invention will now be described with reference to Fig. 21.

[0139] The gas refrigerant separator-cum-refrigerant flow divider DR of the fourteenth embodiment is modified from the sixth embodiment in the shape of the joint portion between the inlet chamber 10 and the speed increasing chamber 20, like the thirteenth embodiment. Further, the configuration of the joint portion is different in the fourteenth embodiment. In the fourteenth embodiment, as shown in Fig. 21, the joint portion between the inlet chamber 10 and the speed increasing chamber 20 has an annular groove portion 17, the diameter d3 of which is greater than both the diameter d1 of the inlet chamber 10 and the diameter d2 of the speed increasing chamber 20.

[0140] As in the thirteenth embodiment, this configuration temporarily retains the refrigerant sent from the inlet chamber 10 by means of the annular groove portion 17 before the refrigerant reaches the speed increasing chamber 20. This increases the amount of the swirling component in the refrigerant. As a result, the gas refrigerant separator-cum-refrigerant flow divider DR of the fourteenth embodiment has the same advantages as the advantages of the gas refrigerant separator-cum-refrigerant flow divider DR of the thirteenth embodiment.

[0141] In other words, like the thirteenth embodiment, the gas refrigerant separator-cum-refrigerant flow divider DR of the fourteenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (11) of the third embodiment and the same advantage as the advantage (18) of the thirteenth embodiment.

(Fifteenth Embodiment)

[0142] A gas refrigerant separator-cum-refrigerant flow divider according to a fifteenth embodiment of the present invention will now be described with reference to Fig. 22.

[0143] The gas refrigerant separator-cum-refrigerant flow divider DR of the fifteenth embodiment has a straight communication passage 25, which is formed in the joint portion between the speed increasing chamber 20 and the outlet chamber 30 of the sixth embodiment. The diameter of the communication passage 25 is substantially equal to the diameter of the communication port 21.

[0144] In this configuration, the interior of the communication passage 25 is a uniform cylindrical space. Accordingly, the communication passage 25 stabilizes the swirl speed of the refrigerant that has entered the communication passage 25 from the speed increasing chamber 20. The refrigerant path in the outlet chamber 30 is enlarged compared to the refrigerant path in the communication port 21. As a result, when the refrigerant reaches the outlet chamber 30 through the communication passage 25, the jet energy of the refrigerant is diffused. That is, the communication port 21 operates as a nozzle for spraying homogeneous refrigerant. The refrigerant in the outlet chamber 30 has a swirling component. Accordingly, a refrigerant flow jetted through the communication port 21 hits the peripheral wall 33 of the outlet chamber 30, thus stabilizing refrigerant flow proceeding along the peripheral wall 33. As a result, the refrigerant in the outlet chamber 30 is divided into uniform flows for the respective flow dividing pipes Pd.

[0145] The gas refrigerant separator-cum-refrigerant flow divider DR of the fifteenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (11) of the third embodiment, like the sixth embodiment. The fifteenth embodiment also has the advantage described below.

(19) Since the communication passage 25 stabilizes the swirl speed of refrigerant, a refrigerant flow in the outlet chamber 30 is stabilized. This stabilizes gas refrigerant extraction and improves refrigerant flow division performance.

(Sixteenth Embodiment)

[0146] A gas refrigerant separator-cum-refrigerant flow divider according to a sixteenth embodiment of the present invention will now be described with reference to Fig. 23.

[0147] In the gas refrigerant separator-cum-refrigerant flow divider DR of the sixteenth embodiment, the communication passage 25, which is shaped as a short straight pipe the diameter of which is substantially equal to the diameter of the communication port 21, is formed in the joint portion between the speed increasing chamber 20 and the outlet chamber 30 of the sixth embodiment continuously from the communication port 21. A conical portion 26, which has a diameter increasing toward the outlet chamber 30, is formed continuously from the communication passage 25. The conical portion 26 is connected directly to the outlet chamber 30.

[0148] In this configuration, the communication passage 25, which has a constant diameter, stabilizes a swirling refrigerant flow after the refrigerant flow is discharged from the speed increasing chamber 20 toward the outlet chamber 30. Further, after the refrigerant enters the conical portion 26 through the communication passage 25, the conical portion 26 gradually increases the swirling diameter of the refrigerant, thus stabilizing the refrigerant flowing into the outlet chamber 30.

[0149] The gas refrigerant separator-cum-refrigerant flow divider DR of the sixteenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (11) of the third embodiment, like the sixth embodiment. The sixteenth embodiment has the advantage described below.

(20) The communication passage 25 having a uniform diameter stabilizes a swirling refrigerant flow and the conical portion 26 ensures a smooth refrigerant flow into the outlet chamber 30. This stabilizes gas refrigerant extraction and improves refrigerant flow division performance.

(Seventeenth Embodiment)

[0150] A gas refrigerant separator-cum-refrigerant flow divider according to a seventeenth embodiment of the present invention will now be described with reference to Fig. 24.

[0151] As illustrated in Fig. 24, the gas refrigerant separator-cum-refrigerant flow divider DR of the seventeenth embodiment is, for example, the gas refrigerant separator-cum-refrigerant flow divider of the sixth embodiment having a filter 27, which is formed in the speed increasing chamber 20, in this case, to remove foreign matter such as dust from refrigerant. The filter 27 is a conically shaped porous permeable material. The filter 27 is fixed to the entire circumference of the end of the speed increasing chamber 20, which has a conical shape, in the vicinity of the inlet chamber 10. The filter 27 has a conically projected shape toward the outlet chamber 30. The porous permeable material for forming the filter 27 may be formed of metal, ceramic, plastic, meshed material, or a porous plate.

[0152] The gas refrigerant separator-cum-refrigerant flow divider DR of the seventeenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (11) of the third embodiment, like the sixth embodiment. The seventeenth embodiment also has the advantage described below.

(21) Generally, it is highly likely that throttle performance of a throttle portion of an expansion valve will be deteriorated by clogging from foreign matter or waste. To avoid this, a filter (a porous permeable material) for catching foreign matter is arranged upstream or downstream of the expansion valve. However, the seventeenth embodiment has the filter 27 arranged inside the gas refrigerant separator-cum-refrigerant flow divider DR. This makes it unnecessary to arrange a separate filter for protecting the expansion valve connected to the refrigerant inlet pipe 11. This saves space for installing the separate filter, thus decreasing the size and cost of the gas refrigerant separator-cum-refrigerant flow divider. Specifically, the filter 27 protects the expansion valve by collecting foreign matter from refrigerant when the refrigerant flows from the flow dividing pipes Pd to the refrigerant inlet pipe 11.

(Eighteenth Embodiment)

[0153] A gas refrigerant separator-cum-refrigerant flow divider DR according to an eighteenth embodiment of the present invention will hereafter be described with reference to Fig. 25.

[0154] The gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment is modified from the gas refrigerant separator-cum-refrigerant flow divider DR of the fifth embodiment in that the eighteenth embodiment has an increased number of flow dividing pipes Pd and a more specified configuration for a container configuring the inlet chamber 10, the speed increasing chamber 20, and the outlet chamber 30.

[0155] Specifically, with reference to Fig. 25(a), the container, which is a component of the gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment, is configured by a member forming the inlet chamber 10, a member having the peripheral wall of the speed increasing chamber 20 and the peripheral wall 33 of the outlet chamber 30 that are formed integrally, and a member forming the side wall 32 of the outlet chamber 30 facing the communication port 21.

[0156] In the member forming the inlet chamber 10, the peripheral wall 13 of the inlet chamber 10 and the side wall 12 of the inlet chamber 10 at the side opposite to the speed increasing chamber 20 are formed integrally with each other and joined together smoothly. The peripheral wall 13 has a diameter increasing toward the speed increasing chamber 20 and is joined to the speed increasing chamber 20. The seventh embodiment also has the peripheral wall 13 with the increasing diameter. The side wall 12 is shaped such that an inner wall surface 12a of the side wall 12 has the shape of an outwardly projected partially spherical portion having a center corresponding to the center axis of the inlet chamber 10. As in the fifth embodiment, the refrigerant inlet pipe 11 is connected to the refrigerant inlet port 14 such that refrigerant is introduced along the inner wall surface of the peripheral wall 13.

[0157] Like the fifth embodiment, the peripheral wall of the speed increasing chamber 20 has a conical shape the diameter of which decreases from the side corresponding to the inlet chamber 10 to the side corresponding to the outlet chamber 30.

[0158] The peripheral wall 33 of the outlet chamber 30 has a conical shape enlarging gradually from the side corresponding to the communication port 21 of the speed increasing chamber 20. In the eighteenth embodiment, the peripheral wall of the speed increasing chamber 20 and the peripheral wall 33 of the outlet chamber 30 are molded integrally and formed as a smooth wall surface curved at the communication port 21, which is located between the speed increasing chamber 20 and the outlet chamber 30.

[0159] The side wall 32 of the outlet chamber 30 is formed by a thick plate-like material. The side wall 32 is cut such that a central part of an inner wall surface 32a of the side wall 32 is curved outward in the shape of a partially spherical portion, or, in other words, the inner wall surface 32a of the side wall 32 is recessed like a curved surface of the partially spherical portion. As illustrated in Fig. 25(b), which is a side view from the side corresponding to the outlet chamber, a number of (specifically eighteen) flow dividing pipe connection holes 32b are formed in the vicinity of the outer periphery of the side wall 32. The flow dividing pipes Pd are connected to the corresponding flow dividing pipe connection holes 32b.

[0160] In the eighteenth embodiment, refrigerant flows in the inlet chamber 10 and the outlet chamber 30 in the manner described below. Refrigerant is introduced from the refrigerant inlet port 14 and moves along the inner peripheral surface of the peripheral wall 13. The refrigerant thus forms a swirling refrigerant flow in the inlet chamber 10, regardless of the mounting posture of the gas refrigerant separator-cum-refrigerant flow divider DR. In the swirling refrigerant flow, density variation causes liquid-rich refrigerant to swirl in the vicinity of the peripheral wall 13 and gas-rich refrigerant to swirl in the central portion. However, since the refrigerant flows into the inlet chamber 10 through the single refrigerant inlet port 14, the center of the swirling refrigerant flow does not necessarily coincide with the center axis of the gas refrigerant separator-cum-refrigerant flow divider DR.

[0161] However, in the eighteenth embodiment, the central part of the inner wall surface 12a of the side wall 12 has the shape of an outwardly projected partially spherical portion. The shape prevents refrigerant from flowing out from the central portion of the swirling refrigerant flow, thus forming a stagnant portion having only a swirling speed component. This corrects the axis of the swirling refrigerant flow to become approximate to the center of the gas refrigerant separator-cum-refrigerant flow divider DR and stabilizes the refrigerant flow. Further, the peripheral wall 13 of the inlet chamber 10 has a diameter increasing toward the speed increasing chamber 20, thus adding a flow component proceeding to the speed increasing chamber 20 to the swirling refrigerant flow. In this manner, the peripheral wall 13 forms a guide wall that guides the refrigerant flow to the speed increasing chamber 20. As a result, regardless of the mounting posture of the gas refrigerant separator-cum-refrigerant flow divider DR, refrigerant is smoothly caused to swirl and directed into the speed increasing chamber 20.

[0162] Refrigerant flows from the speed increasing chamber 20 to the outlet chamber 30 in the manner described below.

[0163] After gaining speed in the speed increasing chamber 20, the swirling refrigerant flow continuously swirls and flows into the outlet chamber 30 through the communication port 21, the diameter of which is not significantly small. At opposite sides of the communication port 21, the peripheral wall of the speed increasing chamber 20 and the peripheral wall of the outlet chamber 30 are formed integrally with each other to form a smooth wall surface curved at the communication port 21, which is located between the two peripheral walls. As a result, when refrigerant passes through the communication port 21, which has a smooth curved surface, unnecessary energy loss does not occur. This maintains intensity of the swirling refrigerant flow when directing the refrigerant into the speed increasing chamber 20.

[0164] Since swirling of the refrigerant flowing into the outlet chamber 30 through the communication port 21 is maintained at an intense level, the refrigerant exhibits such a density distribution that gas-rich refrigerant gathers at the center portion of the flow and liquid-rich flows in the vicinity of the inner wall surface of the peripheral wall 33. In the outlet chamber 30, a liquid membrane is formed along the inner wall surface of the peripheral wall 33 and only gas refrigerant is collected at the middle portion of the outlet chamber 30. The center of the swirling flow is maintained approximately at the center of the gas refrigerant separator-cum-refrigerant flow divider DR and thus stabilized. Particularly, the central part of the inner wall surface 32a of the side wall 32 is shaped like an outwardly projected partially spherical portion. Even if some gas refrigerant flows unevenly to some extent after having been jetted through the vicinity of the middle of the communication port 21, the gas refrigerant is guided to the central part of the side wall 32 and the center of the swirling flow is corrected to collect approximately at the center of the gas refrigerant separator-cum-refrigerant flow divider DR and is thus stabilized.

[0165] The gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9) and (11) of the third embodiment and the same advantage as the advantage (12) of the fourth embodiment, like the fifth embodiment, as well as the same advantage as the advantage (13) of the fifth embodiment. The eighteenth embodiment also has the advantages described below.

(22) The peripheral wall of the speed increasing chamber 20 and the peripheral wall 33 of the outlet chamber 30 are formed as a wall surface curved at the communication port 21, which is arranged between the peripheral walls. This decreases unnecessary energy loss in the refrigerant flowing from the speed increasing chamber 20 to the outlet chamber 30. As a result, an intense swirling refrigerant flow is directed into the outlet chamber 30.

(23) The peripheral wall of the speed increasing chamber 20 and the peripheral wall 33 of the outlet chamber 30 are formed integrally with each other. The inlet chamber 10 is formed independently from the speed increasing chamber 20 and the outlet chamber 30 and joined to the speed increasing chamber 20. This configuration allows the smooth surface curved at the communication port 21 to be an endless curved surface that causes less fluid turbulence. As a result, a swirling refrigerant flow is stably discharged from the speed increasing chamber 20 to the outlet chamber 30.

(24) The central part of the inner wall surface 12a of the side wall 12 of the inlet chamber 10, which is located at the side opposite to the speed increasing chamber 20, has the shape of an outwardly projected partially spherical portion. This corrects the center of a swirling refrigerant flow to gather approximately at the middle of the outwardly projected partially spherical portion in the inlet chamber 10. As a result, the center of the swirling refrigerant flow is stabilized in a position approximately at the center axis of the container configuring the gas refrigerant separator-cum-refrigerant flow divider DR.

(25) The central part of the inner wall surface 32a of the side wall 32 in the outlet chamber 30 is shaped

like an outwardly projected partially spherical portion. This corrects the center of a swirling refrigerant flow produced in the outlet chamber 30 to collect approximately at the middle of the outwardly projected partially spherical portion and stabilizes the center of the swirling refrigerant flow in a position approximately at the axis of the gas refrigerant separator-cum-refrigerant flow divider DR. As a result, the refrigerant is divided into uniform flows for the flow dividing pipes Pd.

(Nineteenth Embodiment)

[0166] A gas refrigerant separator-cum-refrigerant flow divider DR according to a nineteenth embodiment of the present invention will now be described with reference to Fig. 26.

[0167] The nineteenth embodiment is modified from the eighteenth embodiment in the shape of the side wall 12 of the inlet chamber 10. The other components of the nineteenth embodiment are configured identically to the corresponding components of the eighteenth embodiment.

[0168] Specifically, in the gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment, the central part of the side wall 12 of the inlet chamber 10 has the shape of an outwardly projected partially spherical portion. In the nineteenth embodiment, as illustrated in Fig. 26, the central part of the side wall 12 is shaped like an inwardly projected partially spherical portion.

[0169] In the nineteenth embodiment, when flowing from the refrigerant inlet pipe 11 through the refrigerant inlet port 14, refrigerant is guided tangentially with respect to the inner wall surface of the peripheral wall 13 to form a swirling flow, as in the eighteenth embodiment. In this state, the space corresponding to the central part of the inner wall surface 12a of the side wall 12, where minimum pressure acts, is reduced in size and forms a guide wall. This forms a refrigerant flow moving along the surface of the inwardly projected partially spherical portion, thus stabilizing the swirling refrigerant flow.

[0170] The gas refrigerant separator-cum-refrigerant flow divider DR of the nineteenth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9), (11) to (13), (22), (23), and (25), like the eighteenth embodiment. The nineteenth embodiment also has the advantage described below.

(26) In the inlet chamber 10, which forms a swirling refrigerant flow, the central part of the inner wall surface 12a of the side wall 12 has the shape of an inwardly projected partially spherical portion. The space corresponding to the middle portion of the inner wall surface 12a of the side wall 12, where minimum pressure acts, is thus reduced in size and forms a guide wall. As a result, a refrigerant flow is formed along the recessed portion around the inwardly projected portion. This stabilizes swirling refrigerant flow.

(Twentieth Embodiment)

[0171] A gas refrigerant separator-cum-refrigerant flow divider DR according to a twentieth embodiment of the present invention will now be described with reference to Fig. 27.

[0172] The twentieth embodiment is modified from the eighteenth embodiment in the shape of the side wall 32 of the outlet chamber 30. The other components of the twentieth embodiment are configured identically to the corresponding components of the eighteenth embodiment.

[0173] Specifically, in the gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment, the central part of the inner wall surface 32a of the side wall 32 in the outlet chamber 30 is shaped as an outwardly projected partially spherical portion. In contrast, in the twentieth embodiment, the central part of the inner wall surface 32a of the side wall 32 in the outlet chamber 30 is shaped like an inwardly projected partially spherical portion. In other words, the central part of the inner wall surface 32a of the side wall 32 is cut to be inwardly projected like a partially spherical portion.

[0174] In the twentieth embodiment, after entering the outlet chamber 30 through the communication port 21 while being maintained as an intense swirling flow, the refrigerant exhibits such a density distribution that the central portion is gas-refrigerant-rich and the vicinity of the inner wall surface of the peripheral wall 33 is liquid-refrigerant-rich. The center of the swirling flow is maintained in a position approximately at the center of the gas refrigerant separator-cum-refrigerant flow divider DR. The space corresponding to the central part of the inner wall surface 32a of the side wall 32 in the outlet chamber 30, where minimum pressure acts, is thus reduced in size and forms a guide wall. This forms a flow along the surface of the inwardly projected partially spherical portion, thus stabilizing a swirling refrigerant flow.

[0175] The gas refrigerant separator-cum-refrigerant flow divider DR of the twentieth embodiment, which is configured as described above, has the same advantages as the advantages (7) to (9), (11) to (13), and (22) to (24), like the eighteenth embodiment. The twentieth embodiment also has the advantage described below.

(27) In the outlet chamber 30 in which a swirling flow is maintained, the space corresponding to the central part of the inner wall surface 32a of the side wall 32 is reduced in size and forms a guide wall. This forms a flow along the surface of the inwardly projected partially spherical portion, thus stabilizing a swirling refrigerant flow.

(Twenty-First Embodiment)

[0176] A gas refrigerant separator-cum-refrigerant flow divider DR according to a twenty-first embodiment of the present invention will now be described with reference to Fig. 28.

[0177] The twenty-first embodiment is modified from the eighteenth embodiment in the shape of the side wall 12 of the inlet chamber 10. The other components of the twenty-first embodiment are configured identically to the corresponding components of the eighteenth embodiment.

[0178] Specifically, in the gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment, the inner wall surface of the side wall 12 of the outlet chamber 30 substantially as a whole is shaped like an outwardly projected partially spherical portion about the center corresponding to the center axis of the gas refrigerant separator-cum-refrigerant flow divider DR. In contrast, in the inner wall surface of the side wall 12 of the outlet chamber 30 of the twenty-first embodiment, only a portion near the center of the gas refrigerant separator-cum-refrigerant flow divider DR is locally projected outward.

[0179] This configuration also forms a stagnant flow to correct the center of a swirling refrigerant flow in the inlet chamber 10 to a position approximately at the middle of the outwardly projected partially spherical portion. The center of the swirling flow is thus stabilized in the vicinity of the center of the gas refrigerant separator-cum-refrigerant flow divider DR. In other words, the diameter of the outwardly projected partially spherical portion with respect to the inner wall surface 12a does not substantially influence the function of the partially spherical portion.

[0180] The gas refrigerant separator-cum-refrigerant flow divider DR of the twenty-first embodiment has the same advantages as the advantages (7) to (9), (11), (13), and (22) to (25), as in the gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment.

(Twenty-Second Embodiment)

[0181] A gas refrigerant separator-cum-refrigerant flow divider DR according to a twenty-second embodiment of the present invention will now be described with reference to Fig. 29.

[0182] The twenty-second embodiment is modified from the eighteenth embodiment in segmentation of the components configuring the gas refrigerant separator-cum-refrigerant flow divider DR and the configuration of the joint portion between the speed increasing chamber 20 and the outlet chamber 30.

[0183] Specifically, as illustrated in Fig. 29, the container in the gas refrigerant separator-cum-refrigerant flow divider DR of the twenty-second embodiment includes a straight communication passage 25, which is formed in the joint portion between the speed increasing chamber 20 and the outlet chamber 30 of the eighteenth embodiment and has a diameter substantially equal to the diameter of the communication port 21. The joint portion is identical to that of the fifteenth embodiment. The components configuring the gas refrigerant separator-cum-refrigerant flow divider DR include a member configuring the inlet chamber 10 and the speed increasing chamber 20 as an integral body, a member configuring the peripheral wall 33 of the outlet chamber 30, and a member configuring the side wall 32 of the outlet chamber 30 facing the communication port 21.

[0184] In the twenty-second embodiment, after having been directed through the refrigerant inlet port 14, refrigerant forms a swirling flow in the inlet chamber 10. The swirling flow gains speed in the speed increasing chamber 20 and flows into the outlet chamber 30 after having been subjected to nozzle action in the communication passage 25. In the outlet chamber 30, the swirling flow is maintained in a separated gas-liquid state. In this manner, as in the eighteenth embodiment, the center of the swirling flow is corrected to a position approximately at the center of the gas refrigerant separator-cum-refrigerant flow divider DR in the inlet chamber 10, the speed increasing chamber 20, and the outlet chamber 30 and thus the swirling flow is stabilized. The communication passage 25 is formed as an elongated straight passage having a uniform diameter unlike the communication port 21 of the eighteenth embodiment. This stabilizes the swirling speed. Also, the communication passage 25 brings about pronounced nozzle action. Accordingly, even when a pulsating refrigerant flow is sent through the refrigerant inlet pipe 11, uneven density distribution, which causes pulsation, is canceled.

[0185] The gas refrigerant separator-cum-refrigerant flow divider DR of the twenty-second embodiment has the same advantages as the advantages (7) to (9), (11), (13), (24), and (25), like the gas refrigerant separator-cum-refrigerant flow divider DR of the eighteenth embodiment, as well as the same advantage as the advantage (19) of the fifteenth embodiment. The twenty-second embodiment also has the advantage described below.

(28) The gas refrigerant separator-cum-refrigerant flow divider DR is formed by the member configuring the inlet chamber 10 and the speed increasing chamber 20 integrally, the member configuring the peripheral wall 33 of the outlet chamber 30, and the member configuring the side wall 32 of the outlet chamber 30 facing the communication port 21. The member configuring the inlet chamber 10 and the speed increasing chamber 20 integrally is connected to the member configuring the peripheral wall 33 of the outlet chamber 30 at the joint portion. This configuration allows joint of the components configuring the inlet chamber 10, the speed increasing chamber 20, and the outlet chamber 30 in a portion having a small diameter, thus facilitating such joint. As a result, a structural defect such as refrigerant leakage can be easily avoided.

(Twenty-Third Embodiment)

[0186] An expansion valve according to a twenty-third embodiment of the present invention will hereafter be described with reference to Figs. 30 and 31.

[0187] The expansion valve of the twenty-third embodiment is a combination of a typical conventional electric expansion valve and a gas refrigerant separator-cum-refrigerant flow divider DR according to the present invention. Although any one of the above-described gas refrigerant separator-cum-refrigerant flow dividers DR may be combined with the expansion valve, the twenty-third embodiment employs the gas refrigerant separator-cum-refrigerant flow divider DR of the sixth embodiment by way of example. In the following description of the expansion valve, upward, downward, leftward, and rightward directions refer to corresponding directions as viewed in Fig. 30(a). Also, the gas refrigerant separator-cum-refrigerant flow divider DR will be described with reference to Figs. 13.

[0188] As illustrated in Fig. 30(a), the expansion valve of the twenty-third embodiment has a body 50, which substantially has a vertically elongated cylindrical shape. Two pipe joint ports 50a, 50b are formed in the body 50. In this configuration, an inlet pipe 51 is connected to the pipe joint port 50a, which is formed in a side surface of the body 50. An outlet pipe 52 is arranged below the body 50. The gas refrigerant separator-cum-refrigerant flow divider DR of the sixth embodiment is connected to the outlet pipe 52. In this case, the outlet pipe 52 is formed by a short straight pipe and functions also as the aforementioned refrigerant inlet pipe 11. Accordingly, as illustrated in Figs. 30(a) and 30(b), the gas refrigerant separator-cum-refrigerant flow divider DR is arranged such that the axis of the gas refrigerant separator-cum-refrigerant flow divider DR extends horizontally

[0189] With reference to Figs. 31, a valve chamber 53 is formed in the body 50 of the expansion valve. A valve hole 54 is formed in the bottom wall of the valve chamber 53. The valve chamber 53 accommodates a needle valve 55, which is controlled to selectively ascend and descend to separate from or contact the wall around the valve hole 54, thus adjusting the open degree of the valve hole 54. In the expansion valve, the valve hole 54 and the needle valve 55 configure a throttle portion 56. In the twenty-third embodiment, the outlet pipe 52 is connected directly to the refrigerant inlet port 14 (see Figs. 13) of the gas refrigerant separator-cum-refrigerant flow divider DR. That is, the outlet pipe 52 functions also as the refrigerant inlet pipe 11 of the sixth embodiment. The length of the outlet pipe 52 is set at a value suitable for introducing a jet flow from the throttle portion 56 into the inlet chamber 10 through the refrigerant inlet port 14.

[0190] In this configuration, after having been throttled by the expansion valve, a two-phase refrigerant flow is sent into the inlet chamber 10 using intensity of a jet flow through the throttle portion 56. This rapidly forms a swirling refrigerant flow in the inlet chamber 10, gathers liquid refrigerant in the vicinity of the inner wall surface of the peripheral wall 13, and collects gas refrigerant to the swirling central portion. Afterwards, gas refrigerant extraction and refrigerant flow division are carried out basically in the same manner as the sixth embodiment. A refrigerant circuit for a refrigerating apparatus using the expansion valve may be configured by combining and integrally joining the expansion valves 5A, 5B with the gas refrigerant separator-cum-refrigerant flow divider DR illustrated in Fig. 9, for example, according to the twenty-third embodiment.

[0191] The expansion valve of the twenty-third embodiment combined with the gas refrigerant separator-cum-refrigerant flow divider DR, which is configured as described above, has the same advantages as the advantages (7) to (11) of the third embodiment, like the sixth embodiment. The expansion valve also has the advantages described below.

(29) The expansion valve and the gas refrigerant separator-cum-refrigerant flow divider DR are joined integrally with each other through the outlet pipe 52. This simplifies handling of the components.

(30) In the twenty-third embodiment, refrigerant is jetted as mist through the expansion valve and enters the inlet chamber 10 and forms a swirling flow. This greatly decreases influence of gravity on the swirling refrigerant flow. As a result, the expansion valve is mounted in the refrigerating apparatus with greatly improved flexibility.

(31) In the twenty-third embodiment, the expansion valve and the gas refrigerant separator-cum-refrigerant flow divider DR are arranged close to each other. Accordingly, when a two-phase gas-liquid refrigerant flow enters the expansion valve, the swirling flow in the gas refrigerant separator-cum-refrigerant flow divider DR causes a flow adjusting effect to decrease intermittent jet flow fluctuation. As a result, noise typically caused by an intermittent refrigerant flow is decreased.

(Twenty-Fourth Embodiment)

[0192] A refrigerating apparatus according to a twenty-fourth embodiment of the present invention will now be described with reference to Fig. 32.

[0193] The refrigerating apparatus of the twenty-fourth embodiment is modified from the second embodiment, which is the refrigerant circuit illustrated in Fig. 7. In the twenty-fourth embodiment, a gas refrigerant passage 3A formed in the outdoor heat exchanger 3 and a gas refrigerant passage 6B arranged in the indoor heat exchanger 6 are connected to a point in the bypass circuit 7A and the bypass circuit 7B, respectively, which are connected to the corresponding gas refrigerant extracting pipes Pg.

[0194] This configuration causes heat exchange with air using change in sensible heat of the gas refrigerant extracted through each of the gas refrigerant extracting pipes Pg. As a result, the heat exchangers operate with correspondingly improved efficiency.

[0195] The refrigerating apparatus of the twenty-fourth embodiment has the same advantages as the advantages (1) to (6) of the second embodiment and the advantage described below.

(32) Using change in sensible heat of the gas refrigerant extracted through the gas refrigerant extracting pipes Pg, heat exchange efficiency is enhanced.

(Twenty-Fifth Embodiment)

[0196] A refrigerating apparatus according to a twenty-fifth embodiment of the present invention will now be described with reference to Fig. 33.

[0197] The refrigerating apparatus of the twenty-fifth embodiment is modified from the fourth embodiment, which is the refrigerant circuit illustrated in Fig. 11. In the twenty-fifth embodiment, a supercooling heat exchanger 7C and a supercooling heat exchanger 8C are arranged in the bypass circuit 7A, 7B, respectively, which are connected to the corresponding gas refrigerant extracting pipes Pg. The supercooling heat exchangers 7C, 8C are connected to the passages at the inlet sides of the associated expansion valves 5A, 5B.

[0198] In the configuration, each one of the supercooling heat exchangers 7C, 8C causes heat exchange between the gas refrigerant extracted through the corresponding one of the gas refrigerant extracting pipes Pg and the liquid refrigerant at the inlet side of the associated one of the expansion valves 5A, 5B. The refrigerant flowing into each expansion valve 5A, 5B is thus cooled using sensible heat of the gas refrigerant extracted through the corresponding gas refrigerant extracting pipe Pg. This also decreases dryness of the refrigerant flowing into the expansion valves 5A, 5B, thus improving refrigerating performance.

[0199] The refrigerating apparatus of the twenty-fifth embodiment has the same advantages as the advantages (7) to (9), (11), and (12) of the fourth embodiment and the advantage described below.

(33) The refrigerant entering the expansion valves 5A, 5B is cooled using sensible heat of the extracted gas refrigerant. This reduces dryness of the refrigerant flowing into each expansion valve 5A, 5B, thus decreasing intermittent refrigerant noise in the expansion valves 5A, 5B.

(modifications)

[0200] The gas refrigerant separator, the gas refrigerant separator-cum-refrigerant flow divider, and the refrigerating apparatus according to the present invention are not restricted to the forms of the illustrated embodiments but may be embodied by modifying or combining different components of different embodiments as necessary. Also, the gas refrigerant separator, the gas refrigerant separator-cum-refrigerant flow divider, and the refrigerating apparatus are not restricted to the illustrated embodiments but may be modified to the forms described below. In these cases, each of the modifications is not only used in the designated one of the embodiments but may be combined with another embodiment or another modification as necessary.

[0201] In the first embodiment, the outlet chamber 30 has the basic configuration III. However, when the gas refrigerant extracting pipe Pg is connected to the inlet chamber 10 as in the first embodiment, the outlet chamber 30 may have the basic configuration I, II, or IV,

[0202] The outlet chamber 30 of the second embodiment has the basic configuration III. However, when the double pipe structure having the refrigerant outlet pipe 31 as the outer pipe and the gas refrigerant extracting pipe Pg as the inner pipe is employed as in the second embodiment, the outlet chamber 30 may have the basic configuration IV.

[0203] In the third embodiment, the outlet chamber 30 has the basic configuration II. However, when the refrigerant outlet pipe 31 is modified to the flow dividing pipes Pd and the gas refrigerant extracting pipe Pg is connected to the center of the inlet chamber 10 as in the third embodiment, the outlet chamber 30 may have the basic configuration I, III, or IV.

[0204] In each of the gas refrigerant separator-cum-refrigerant flow dividers DR of the fourth, fifth, seventh to twelfth, and eighteenth to twenty-second embodiments, the gas refrigerant extracting pipe Pg is connected to the outlet chamber 30. However, the gas refrigerant extracting pipe Pg may be connected to the inlet chamber 10. Specifically, if the outlet chamber has the basic configuration III or IV as in these embodiments, gas refrigerant is collected to the central portions of the inlet chamber 10 and the outlet chamber 30. As a result, the gas refrigerant extracting pipe Pg may be connected to either one of the inlet chamber 10 and the outlet chamber 30.

[0205] By modifying the flow dividing pipes Pd to the refrigerant outlet pipe 31 in the gas refrigerant separator-cum-refrigerant flow divider DR according to any one of the third to twenty-second embodiments, a gas refrigerant separator configured similarly to the gas refrigerant separator-cum-refrigerant flow divider DR may be provided.

[0206] In each of the illustrated embodiments, the speed increasing chamber 20 substantially has a conical shape having a diameter decreasing toward the outlet chamber 30 at a constant rate. However, the speed increasing chamber 20 is not restricted to this shape. Specifically, the speed increasing chamber 20 may have a shape having an inclination angle changing in a stepped manner as illustrated in Figs. 34(a) and 34(b). Alternatively, with reference to Fig. 34(c), the speed increasing chamber 20 have a shape having an inclination angle that varies smoothly in a curved manner. In either case, the speed increasing chamber 20 has a tapered or curved surface such that the diameter of a swirling flow becomes smaller toward the outlet port of the speed increasing chamber. This increases the speed of the swirling refrigerant flow flowing from the inlet chamber 10, as in the illustrated embodiments.

[0207] In each of the gas refrigerant separator-cum-refrigerant flow dividers DR of the third, sixth, and thirteenth to eighteenth embodiments in which the gas refrigerant extracting pipe Pg is connected to the inlet chamber 10, the plane defined by the opening of the communication port 21 of the speed increasing chamber 20 may be inclined. In other words, although the plane defined by the opening of the communication port 21 of the speed increasing chamber 20 is a flat plane extending perpendicular to the center axis of the outlet chamber 30 in these embodiments, the present invention is not restricted to this. For example, as illustrated in Fig. 35, the plane defined by the opening of the communication port 21 of the speed increasing chamber 20 may be inclined with respect to the center axis of the outlet chamber 30. This configuration regulates the flow direction of the refrigerant proceeding from the speed increasing chamber 20 into the outlet chamber 30 at the time when the refrigerant enters the outlet chamber 30. The configuration is thus preferable for a case in which refrigerant flow amounts are regulated to vary from one flow dividing pipe Pd to another.

[0208] In the gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR according to any one of the first to third, fifth, sixth, and ninth to seventeenth embodiments, the inlet chamber 10 may have a conical shape as in the case of the seventh embodiment. This achieves the advantage (13) of the seventh embodiment.

[0209] In the gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR according to any one of the first to third, fifth, sixth, and ninth to seventeenth embodiments, the inlet chamber 10 may have an inclined cylindrical shape as in the case of the eighth embodiment. This achieves the advantage (13) of the seventh embodiment.

[0210] The gas refrigerant separator-cum-refrigerant flow divider DR of any one of the ninth to thirteenth embodiments is modified from the gas refrigerant separator-cum-refrigerant flow divider DR of the fourth embodiment by adding the flow adjusting portion 14a. The flow adjusting portion 14a may be added also to the gas refrigerant separator or the gas refrigerant separator-cum-refrigerant flow divider of any one of the other embodiments.

[0211] The gas refrigerant separator-cum-refrigerant flow divider DR of the thirteenth embodiment is modified from the gas refrigerant separator-cum-refrigerant flow divider of the sixth embodiment by adding the step 16. The step 16 may be added also to the gas refrigerant separator or the gas refrigerant separator-cum-refrigerant flow divider of any one of the other embodiments.

[0212] The gas refrigerant separator-cum-refrigerant flow divider DR of the fourteenth embodiment is modified from the gas refrigerant separator-cum-refrigerant flow divider of the sixth embodiment by adding the annular groove portion 17. The annular groove portion 17 may be added also to the gas refrigerant separator or the gas refrigerant separator-cum-refrigerant flow divider of any one of the other embodiments.

[0213] The gas refrigerant separator-cum-refrigerant flow divider DR of the fifteenth embodiment is modified from the gas refrigerant separator-cum-refrigerant flow divider of the sixth embodiment by adding the straight communication passage 25, which is formed in the joint portion between the speed increasing chamber 20 and the outlet chamber 30 and has a diameter substantially equal to the diameter of the communication port 21. However, the present invention is not restricted to this. The straight communication passage 25 may be added also to the gas refrigerant separator or the gas refrigerant separator-cum-refrigerant flow divider of any one of the other embodiments.

[0214] The gas refrigerant separator-cum-refrigerant flow divider DR of the sixteenth embodiment is modified from the gas refrigerant separatar-cum-refrigerant flow divider of the sixth embodiment by adding the short straight communication passage 25, which is formed in the joint portion between the speed increasing chamber 20 and the outlet chamber 30 and has a diameter substantially equal to the diameter of the communication port 21, and the conical portion 26 having a diameter increasing toward the outlet chamber 30. However, the present invention is not restricted to this. The straight communication passage 25 and the conical portion 26 may be added also to the gas refrigerant separator or the gas refrigerant separator-cum-refrigerant flow divider of any one of the other embodiments.

[0215] The filter for removing foreign matter such as dust from refrigerant is mounted in the gas refrigerant separator-cum-refrigerant flow divider DR of the seventeenth embodiment. The filter may be employed in the gas refrigerant separator or the gas refrigerant separator-cum-refrigerant flow divider of any one of the other embodiments.

[0216] In the expansion valve of the twenty-third embodiment, the gas refrigerant separator-cum-refrigerant flow divider DR of the sixth embodiment is connected integrally to a typical expansion valve. However, the gas refrigerant separator-cum-refrigerant flow divider DR of any one of the other embodiments may be connected to the expansion valve.

[0217] In the expansion valve of the twenty-third embodiment, the gas refrigerant separator-cum-refrigerant flow divider DR is connected integrally to the expansion valve. Instead of this configuration, the gas refrigerant separator SG may be connected integrally to the expansion valve and a refrigerant flow divider, which is a separate body, may be connected to the gas refrigerant separator SG as in conventional cases.

[0218] In the expansion valve of the twenty-third embodiment, the outlet pipe 52 is connected to the pipe joint port 50b, which is formed in the lower portion of the body of the expansion valve, and the gas refrigerant separator-cum-refrigerant flow divider DR is connected to the outlet pipe 52. However, the present invention is not restricted to this. In other words, with reference to Figs. 36, the outlet pipe 52 may be connected to the pipe joint port 50a, which is formed in the side surface of the expansion valve. The gas refrigerant separator-cum-refrigerant flow divider DR is connected to the outlet pipe 52. Also, in these cases, the orientation of the gas refrigerant separator-cum-refrigerant flow divider DR may be reversed in the axial direction.

[0219] The device to which the gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR according to the present invention is connected is not restricted to the expansion valve as in the above-described cases. For example, the gas refrigerant separator SG of the invention may be connected to a device that generates a two-phase gas-liquid flow, such as an orifice, a nozzle, or an ejector. The gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR may thus be used in combination with the device to separate gas refrigerant from refrigerant sent from the aforementioned device.

[0220] A gas refrigerant separator-cum-refrigerant flow divider DR illustrated in Fig. 37 is an example of a combination of different components from different ones of the illustrated embodiments. Specifically, the illustrated gas refrigerant separator-cum-refrigerant flow divider DR is the gas refrigerant separator-cum-refrigerant flow divider DR of the fifteenth embodiments in which the inlet chamber 10 is conically shaped like the inlet chamber 10 of the seventh embodiment and the step 16 is formed in the joint portion between the inlet chamber 10 and the speed increasing chamber 20 as in the thirteenth embodiment. Also in this case, the characteristics of the components are effectively brought about.

[0221] A gas refrigerant separator-cum-refrigerant flow divider DR illustrated in Fig. 38 is another example of a combination of different components from different embodiments. Specifically, the illustrated gas refrigerant separator-cum-refrigerant flow divider DR is the gas refrigerant separator-cum-refrigerant flow divider DR of the sixteenth embodiment in which the inlet chamber 10 is conically shaped like the inlet chamber 10 of the seventh embodiment and the step 16 is formed in the joint portion between the inlet chamber 10 and the speed increasing chamber 20 as in the thirteenth embodiment. Also in this case, the components effectively exhibit their characteristics.

[0222] In the third to seventeenth embodiments, the three flow dividing pipes Pd are circumferentially arranged and spaced apart at equal pitches. However, the number or arrangement of the flow dividing pipes Pd is not restricted to this. For example, four or more flow dividing pipes Pd may be arranged in a circumferential direction and spaced apart at equal pitches or two flow dividing pipes Pd may be employed. Since the eighteenth to twenty-second embodiments each include a great number of flow dividing pipes Pd, which are eighteen flow dividing pipes Pd, each of these embodiments may be used in a large-sized apparatus.

[0223] In each of the refrigerating apparatuses illustrated in Figs. 3, 7, 9, 11, 27, and 28, the gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR according to any one of the first to fourth embodiments is employed. However, in these apparatuses, the gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR according to any one of the other embodiments or any one of the modifications may be used. Alternatively, as in the twenty-third embodiment, the gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR may be connected integrally to the expansion valve.

[0224] In the refrigerating apparatuses illustrated in Figs. 3, 7, 9, 11, 27, and 28, the check valves 8A, 8B are arranged in the corresponding bypass circuits 7A, 7B. However, an on-off valve or a fully closable flow control valve may be employed instead of each of the check valves 8A, 8B. In these cases, to prevent the gas discharged from the compressor 1 from flowing in the bypass passages 7A, 7B using the on-off valves or the flow control valves, not the check valves 8A, 8B, the on-off valves or the flow control valves may be closed. Further, in an operating mode allowing gas refrigerant to pass through the bypass circuits 7A, 7B, the on-off valves or the flow control valves regulate the bypassing amount to adjust the degree of superheating of the gas refrigerant returning to the compressor to an appropriate value. In this manner, the amount of the gas refrigerant extracted from the gas refrigerant separator SG or the gas refrigerant separator-cum-refrigerant flow divider DR is maximized. Also, if an on-off valve for flow control or a flow control valve is mounted in each of the bypass circuits 7A, 7B to accomplish the above-described operation, the on-off valves or the flow control valves may be arranged in series with the corresponding check valves 8A, 8B in the bypass circuits 7A, 7B. In this configuration, unnecessary refrigerant circulation through the bypass circuits is prevented without operating the on-off valves or the flow control valves.

[0225] In the first to seventeenth embodiments, the inlet chamber, the speed increasing chamber, and the outlet chamber have non-chamfered edge portions and joint portions. However, as in the eighteenth to twenty-second embodiments, these edge portions and joint portions may be rounded appropriately to have smooth shapes when the apparatuses are actually manufactured.

[0226] In each of the gas refrigerant separatar-cum-refrigerant flow dividers DR of the eighteenth, nineteenth, twenty-first, and twenty-second embodiments, the central part of the inner wall surface of the side wall 32 in the outlet chamber 30 is shaped like an outwardly projected partially spherical portion. The central portion of the inner wall surface of the side wall 32 may be configured in the same manner even for the outlet chamber 30 having the basic configuration III as in the fourth embodiment or the outlet chamber 30 having the basic configuration IV as in the fifth embodiment.

[0227] In the gas refrigerant separator-cum-refrigerant flow divider DR of the twentieth embodiment, the central portion of the inner wall surface of the side wall 32 in the outlet chamber 30 is shaped like an inwardly projected partially spherical portion. The central part of the inner wall surface of the side wall 32 may be configured in the same manner even for the outlet chamber 30 having the basic configuration III as in the fourth embodiment or the outlet chamber 30 having the basic configuration IV as in the fifth embodiment.

In each of the gas refrigerant separator-cum-refrigerant flow dividers DR of the eighteenth and twentieth to twenty-second embodiments, the central part of the inner wall surface of the side wall 12 in the inlet chamber 10 is shaped like an outwardly projected partially spherical portion. The central portion of the inner wall surface of the side wall 12 of the inlet chamber 10 may be configured in the same manner in the other embodiments.

[0228] In the gas refrigerant separator-cum-refrigerant flow divider DR of the nineteenth embodiment, the central part of the inner wall surface of the side wall 12 in the inlet chamber 10 is shaped like an inwardly projected partially spherical portion. The central portion of the inner wall surface of the side wall 12 of the inlet chamber 10 may be configured in the same manner in the other embodiments.

DESCRIPTION OF THE REFERENCE NUMERALS

[0229] d1, d2, d3...diameter, DR...gas refrigerant separator-cum-refrigerant flow divider, Pd...flow dividing pipe (serving as refrigerant outlet pipe), Pg...gas refrigerant extracting pipe, r1, r2... radius, SG... gas refrigerant separator, 3...outdoor heat exchanger (operating as heating evaporator), 6... indoor heat exchanger (operating as cooling evaporator), 5A, 58... expansion valve, 7A, 7B...bypass circuit, 7C, 8C... supercooling heat exchanger, 8A, 8B...check valve, 10... inlet chamber, 12, 32... side wall, 12a, 32a... inner wall surface, 13, 33... peripheral wall, 14... refrigerant inlet port, 14a...flow adjusting portion, 16...step, 17...annular groove portion, 20...speed increasing chamber, 21...communication port, 25...communication passage, 26...conical portion, 27...filter, 30...outlet chamber, 31...refrigerant outlet pipe, 51...inlet pipe, 52...outlet pipe, 56...throttled portion

Claims

1. A gas refrigerant separator **characterized by**:

   an inlet chamber that guides refrigerant in a two-phase gas-liquid state along an inner wall surface of a peripheral wall of a chamber having a circular cross section, the refrigerant being caused to swirl along the inner wall surface;

   a speed increasing chamber that has a circular cross section and is joined coaxially with the inlet chamber in the axial direction, the speed increasing chamber increasing the speed of a swirling refrigerant flow directed from the inlet chamber into the speed increasing chamber;

   an outlet chamber that is joined coaxially with the speed increasing chamber in the axial direction and has a circular cross section, the outlet chamber receiving the swirling refrigerant flow flowing through a communication port formed at a distal end of the speed increasing chamber, the diameter of the outlet chamber being greater than the opening diameter of the communication port;

   a refrigerant inlet port formed in the inner wall surface of the peripheral wall of the inlet chamber;

   a refrigerant outlet pipe for discharging the refrigerant from the outlet chamber after gas refrigerant has been separated and extracted from the refrigerant; and

   a gas refrigerant extracting pipe for extracting the gas refrigerant collected at a center portion of the swirling refrigerant flow.

2. The gas refrigerant separator according to claim 1, **characterized in that** the speed increasing chamber is configured to increase the speed of the swirling flow by causing the refrigerant that has been directed from the inlet chamber to swirl along an inner wall surface of a peripheral wall shaped like a surface tapered or curved toward the communication port.

3. The gas refrigerant separator according to claim 1 or 2, **characterized in that** the outlet chamber has a cylindrical shape, wherein the diameter of the communication port of the speed increasing chamber and the diameter and the axial dimension of the outlet chamber are selected such that the refrigerant that has been directed from the speed increasing chamber is caused to swirl in the outlet chamber and the center portion of the swirling contains only the gas refrigerant.

4. The gas refrigerant separator according to claim 1 or 2, **characterized in that** the outlet chamber has a conical shape gradually enlarging from the speed increasing chamber toward the distal end, wherein the diameter of the communication port of the speed increasing chamber and the maximum diameter and the axial dimension of the outlet chamber are selected such that the refrigerant that has been directed from the speed increasing chamber is caused to swirl in the outlet chamber and that a middle portion of

the swirling contains only the gas refrigerant.

5. The gas refrigerant separator according to claim 4, **characterized in that** the peripheral wall of the speed increasing chamber and the peripheral wall of the speed increasing chamber are formed by wall surfaces that form a smoothly curved surface with the communication port located therebetween.

6. The gas refrigerant separator according to claim 5, **characterized in that** the speed increasing chamber and the outlet chamber are formed integrally with each other, wherein the inlet chamber is formed independently and joined to the speed increasing chamber.

7. The gas refrigerant separator according to claim 1 or 2, **characterized in that** the diameter of the communication port of the speed increasing chamber and the diameter and the axial dimension of the outlet chamber are selected such that, in the outlet chamber, the refrigerant directed from the speed increasing chamber is blown toward and caused to strike the peripheral wall through centrifugal force produced by the swirling flow and is thus stirred in the outlet chamber.

8. The gas refrigerant separator according to claim 1 or 2, **characterized in that** the diameter of the communication port of the speed increasing chamber is selected such that, in the outlet chamber, the refrigerant directed from the speed increasing chamber is subjected to a throttle effect in the communication port and thus sprayed in a homogeneous gas-liquid distribution state.

9. The gas refrigerant separator according to any one of claims 1 to 8, **characterized in that** the gas refrigerant extracting pipe is configured to extract the gas refrigerant that has been separated and collected at a center of the refrigerant swirling in the inlet chamber.

10. The gas refrigerant separator according to any one of claims 3 to 6, **characterized in that** the gas refrigerant extracting pipe is configured to extract the gas refrigerant that has been separated and collected at a center of the refrigerant swirling in the outlet chamber.

11. The gas refrigerant separator according to claim 10, **characterized in that** the gas refrigerant extracting pipe is configured to extract the gas refrigerant that has been separated and collected at the center of the refrigerant swirling in the outlet chamber, wherein the refrigerant outlet pipe is formed as an outlet pipe having a large diameter and is connected to the outlet chamber to direct liquid-rich refrigerant swirling around the gas refrigerant extracting pipe to the exterior, and the gas refrigerant extracting pipe is inserted in the refrigerant outlet pipe to form an inner pipe of a double pipe structure having the refrigerant outlet pipe as an outer pipe.

12. The gas refrigerant separator according to any one of claims 1 to 11, **characterized in that** the inlet chamber has a cylindrical shape.

13. The gas refrigerant separator according to any one of claims 1 to 11, **characterized in that** the inlet chamber substantially has a conical shape having a diameter increasing toward the speed increasing chamber.

14. The gas refrigerant separator according to any one of claims 1 to 11, **characterized in that** the inlet chamber has an inclined cylindrical shape, wherein the inlet chamber is inclined in a direction in which refrigerant flow introduced therein is guided to the speed increasing chamber.

15. The gas refrigerant separator according to any one of claims 1 to 14, **characterized in that** the inlet chamber has a flow adjusting portion that is formed in the refrigerant inlet port to apply a swirling component to a refrigerant flow introduced therein.

16. The gas refrigerant separator according to any one of claims 1 to 15, **characterized in that** a central part of an inner wall surface of a side wall of the inlet chamber at the side opposite to the speed increasing chamber has an outwardly projected partially spherical shape.

17. The gas refrigerant separator according to any one of claims 1 to 15, **characterized in that** a central part of an inner wall surface of a side wall of the inlet chamber at the side opposite to the speed increasing chamber has an inwardly projected partially spherical shape.

18. The gas refrigerant separator according to any one of claims 1 to 10 and 12 to 16, **characterized in that** a central part of an inner wall surface of a side wall of the outlet chamber that faces the communication port of the speed increasing chamber has an outwardly projected partially spherical shape.

19. The gas refrigerant separator according to any one of claims 1 to 10 and 12 to 16, **characterized in that** a central part of an inner wall surface of a side wall of the outlet chamber that faces the communication port of the speed increasing chamber has an inwardly projected partially spherical shape.

20. The gas refrigerant separator according to any one of claims 1 to 19, **characterized in that** a step is formed in a joint portion between the inlet chamber and the speed increasing chamber such that the diameter of the inlet chamber is greater than the diameter of the speed increasing chamber.

21. The gas refrigerant separator according to any one of claims 1 to 19, **characterized in that** an annular groove portion having a diameter greater than both the diameter of the inlet chamber and the diameter of the speed increasing chamber is formed in a joint portion between the inlet chamber and the speed increasing chamber.

22. The gas refrigerant separator according to any one of claims 1 to 4 and 7 to 21, **characterized in that** a straight communication passage having a diameter substantially equal to the diameter of the communication port is formed in a joint portion between the speed increasing chamber and the outlet chamber.

23. The gas refrigerant separator according to any one of claims 1 to 4 and 7 to 21, **characterized in that** a conical portion having a diameter increasing toward the outlet chamber, starting from the diameter of the communication port, is formed in a joint portion between the speed increasing chamber and the outlet chamber, wherein the conical portion is connected directly to the outlet chamber.

24. The gas refrigerant separator according to any one of claims 1 to 23, **characterized in that** the speed increasing chamber and the outlet chamber are formed separately from each other and joined together at a joint portion between the speed increasing chamber and the outlet chamber.

25. The gas refrigerant separator according to any one of claims 1 to 24, **characterized in that** a filter for removing undesirable matter from the refrigerant is mounted in the gas refrigerant separator.

26. A gas refrigerant separator-cum-refrigerant flow divider **characterized in that**
the refrigerant outlet pipe of the gas refrigerant separator according to any one of claims 1 to 25 is configured as a plurality of flow dividing pipes connected to a plurality of refrigerant passages in an evaporator, and
the flow dividing pipes are spaced apart at equal intervals along a circumference spaced from the axis by a certain distance, the flow dividing pipes being formed such that the radius of an inscribed circle of the flow dividing pipes is greater than the radius of the communication port and that the radius of the outlet chamber is smaller than or equal to the radius of an inscribed circle of the refrigerant inlet port.

27. The gas refrigerant separator-cum-refrigerant flow divider according to claim 26, **characterized in that** the outlet chamber is formed such that the flow dividing pipes are arranged in the vicinity of the peripheral wall of the outlet chamber.

28. The gas refrigerant separatar-cum-refrigerant flow divider according to claim 26 or 27, **characterized in that** the communication port of the speed increasing member is formed such that the communication port has an inclined end surface.

29. An expansion valve having an inlet pipe, an outlet pipe, and a throttle portion formed in the expansion valve, the expansion valve being **characterized in that** the gas refrigerant separator according to any one of claims 1 to 25 is connected to the outlet pipe, a refrigerant jet flow through the throttle portion being introduced into the inlet chamber via the outlet pipe.

30. An expansion valve having an inlet pipe, an outlet pipe, and a throttle portion formed in the expansion valve, the expansion valve being **characterized in that** the gas refrigerant separator-cum-refrigerant flow divider according to any one of claims 26 to 28 is connected to the outlet pipe, a refrigerant jet flow through the throttle portion being introduced into the inlet chamber via the outlet pipe.

31. A refrigerating apparatus **characterized in that**
the gas refrigerant separator according to any one of claims 1 to 25 is connected to an outlet side of an expansion valve,
the refrigerant outlet pipe is connected to a plurality of refrigerant pipes of an evaporator through the flow dividing pipes, and
the gas refrigerant extracting pipe bypasses refrigerant passages for directing divided flows of the refrigerant and is connected to an outlet side of the evaporator.

32. A refrigerating apparatus **characterized in that**
the gas refrigerant separator-cum-refrigerant flow divider according to any one of claims 26 to 28 is connected to an outlet side of an expansion valve,
the flow dividing pipes are connected to a plurality of refrigerant passages in an evaporator, and
the gas refrigerant extracting pipe bypasses the refrigerant passages and is connected to an outlet side of the evaporator.

33. A refrigerating apparatus using the expansion valve according to claim 29 or 30, **characterized in that** the refrigerant outlet pipe is connected to a plurality of refrigerant passages in an evaporator and that the gas refrigerant extracting pipe bypasses the refrigerant passages and is connected to an outlet side of the evaporator.

34. The refrigerating apparatus according to any one of claims 31 to 33, **characterized in that** the gas refrigerant extracting pipe is connected directly to an outlet pipe of the evaporator.

35. The refrigerating apparatus according to any one of claims 31 to 33, **characterized in that** the gas refrigerant extracting pipe is connected to an outlet pipe of the evaporator via a gas refrigerant passage formed in the evaporator.

36. The refrigerating apparatus according to any one of claims 31 to 33, **characterized in that** the gas refrigerant extracting pipe is connected to an outlet pipe of the evaporator via a supercooling heat exchanger arranged at an inlet side of the expansion valve, the supercooling heat exchanger causing heat exchange with liquid refrigerant at an inlet side of the expansion valve.

37. The refrigerating apparatus according to any one of claims 31 to 36, **characterized in that** a flow control valve is arranged in a circuit through which the gas refrigerant extracting pipe is connected to an outlet of the evaporator.

38. The refrigerating apparatus according to any one of claims 31 to 36, **characterized in that** a refrigerant circuit is configured as a heat pump cycle capable of performing a reversible cycle and that a check valve for preventing a refrigerant flow from an outlet of the evaporator to the gas refrigerant extracting pipe is arranged in a circuit through which the gas refrigerant extracting pipe is connected to the outlet of the evaporator.

39. The refrigerating apparatus according to any one of claims 31 to 36, **characterized in that** a refrigerant circuit is configured as a heat pump cycle capable of performing a reversible cycle, that a fully closable flow control valve is arranged in a circuit through which the gas refrigerant extracting pipe is connected to an outlet of the evaporator, and that the flow control valve is fully closed in an operating cycle in which a refrigerant flow from the outlet of the evaporator to the gas refrigerant extracting pipe is produced.

Fig.1 (a)

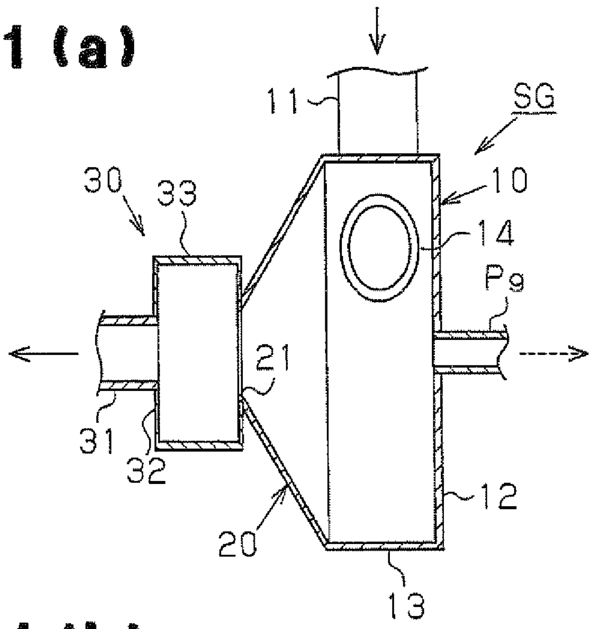


Fig.1 (b)

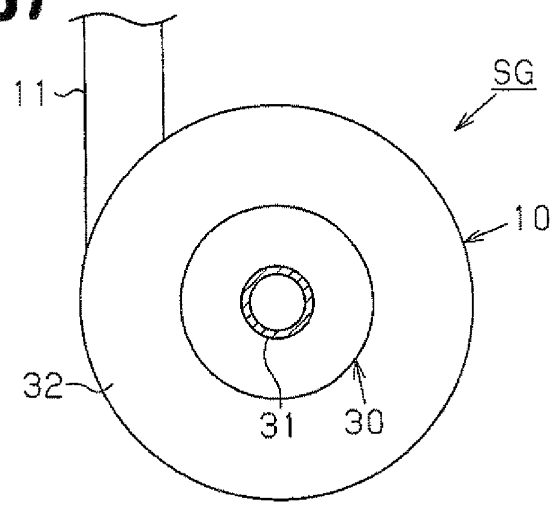


Fig.1 (c)

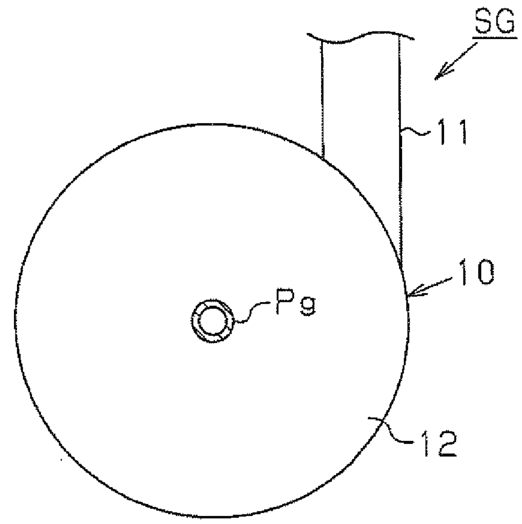


Fig.2(a)

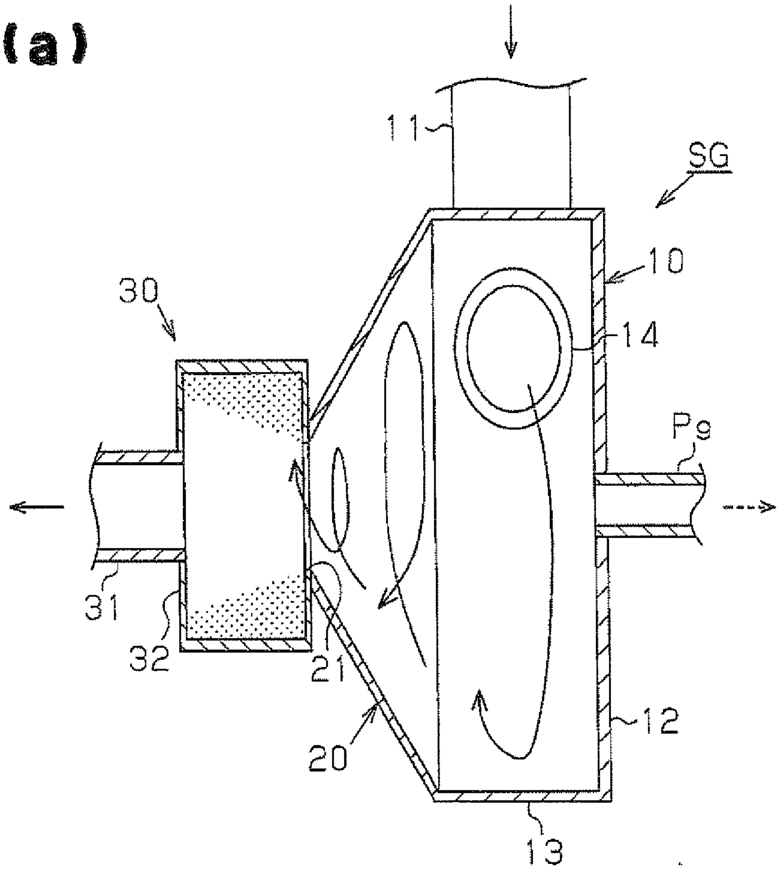
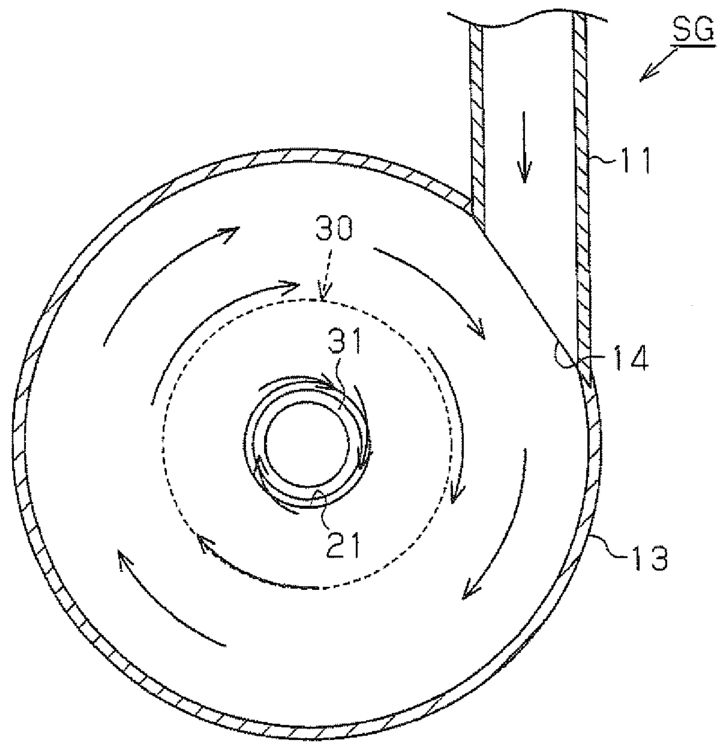


Fig.2(b)



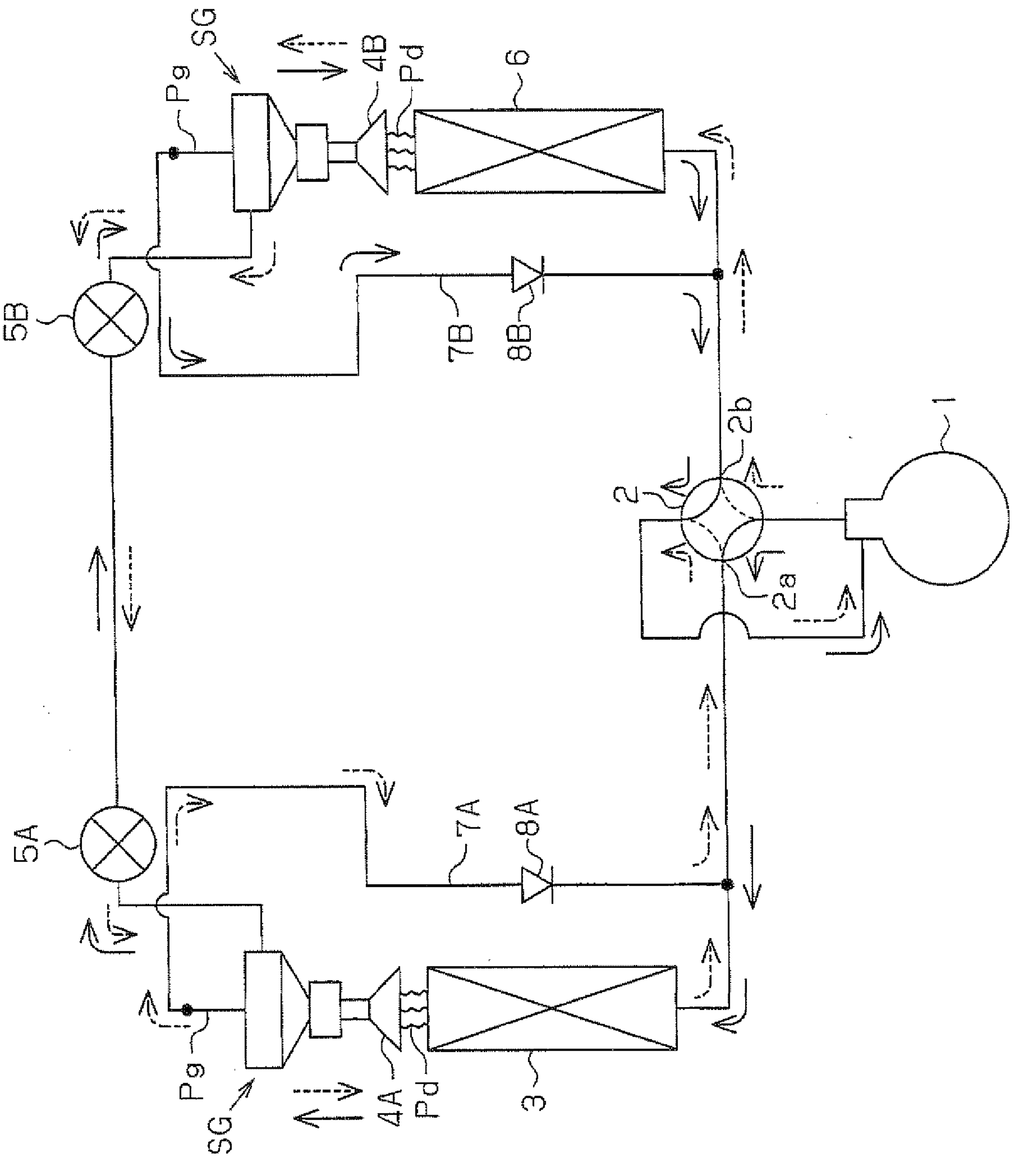


Fig.3

Fig.4

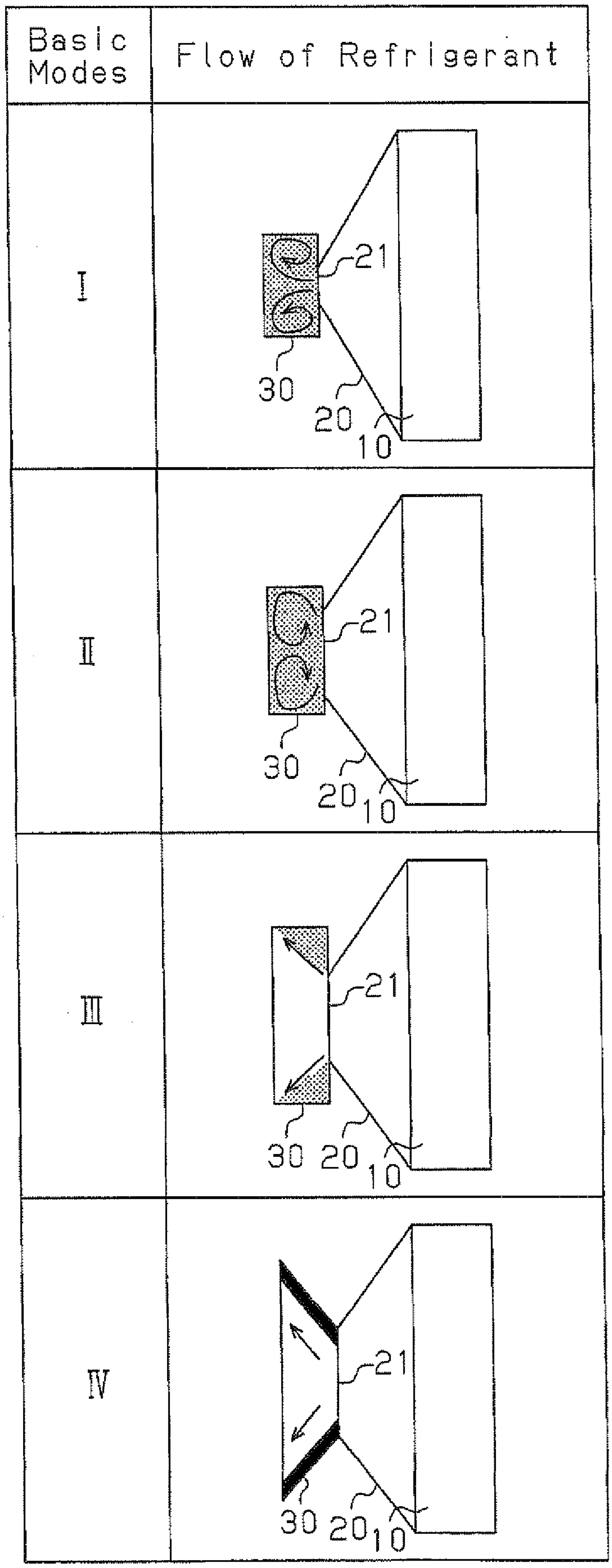


Fig.5(a)

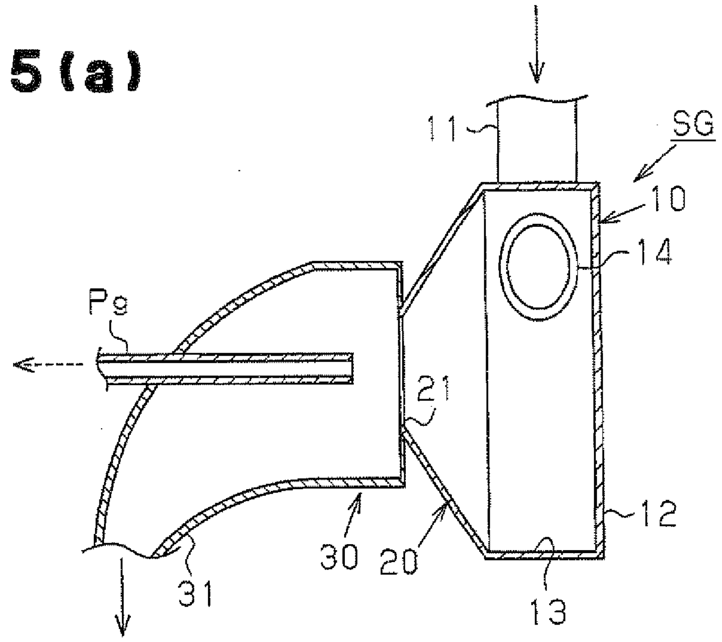


Fig.5(b)

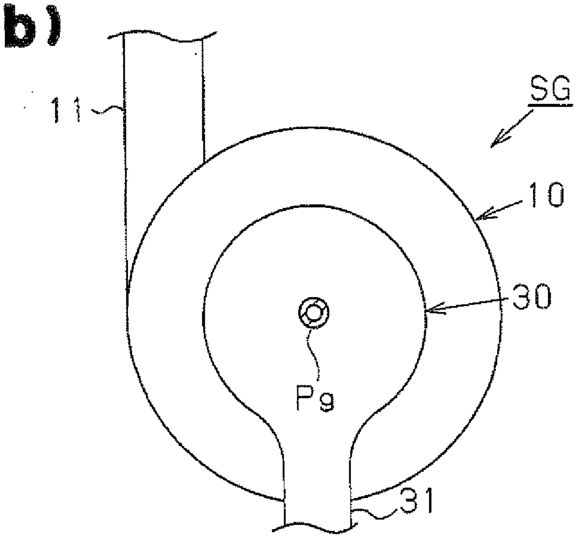


Fig.5(c)

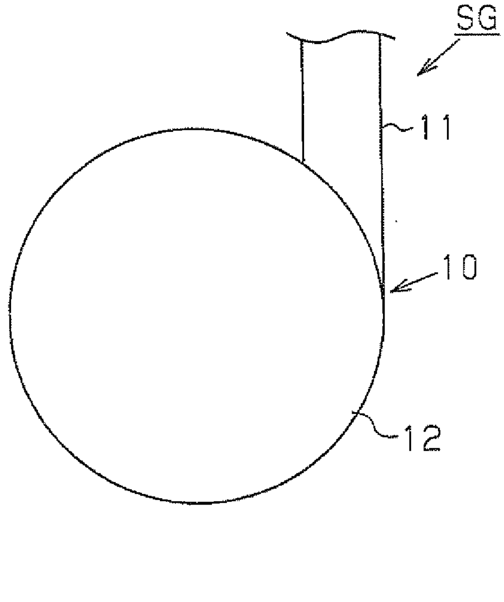


Fig.6(a)

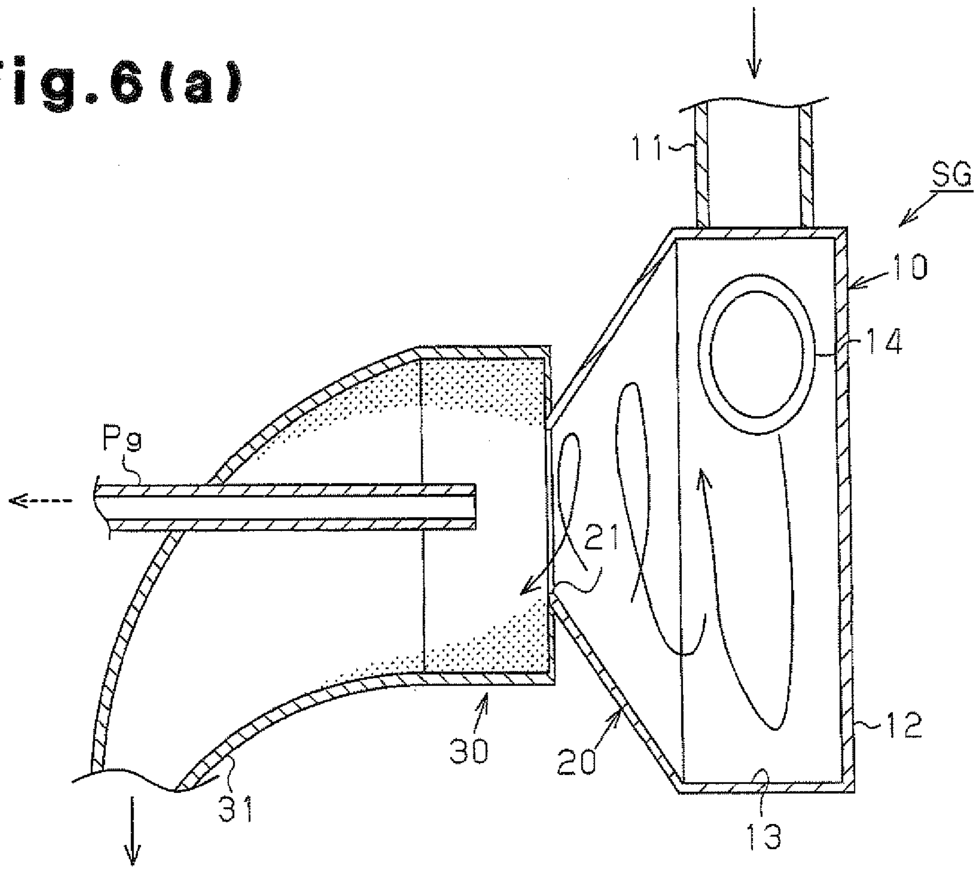
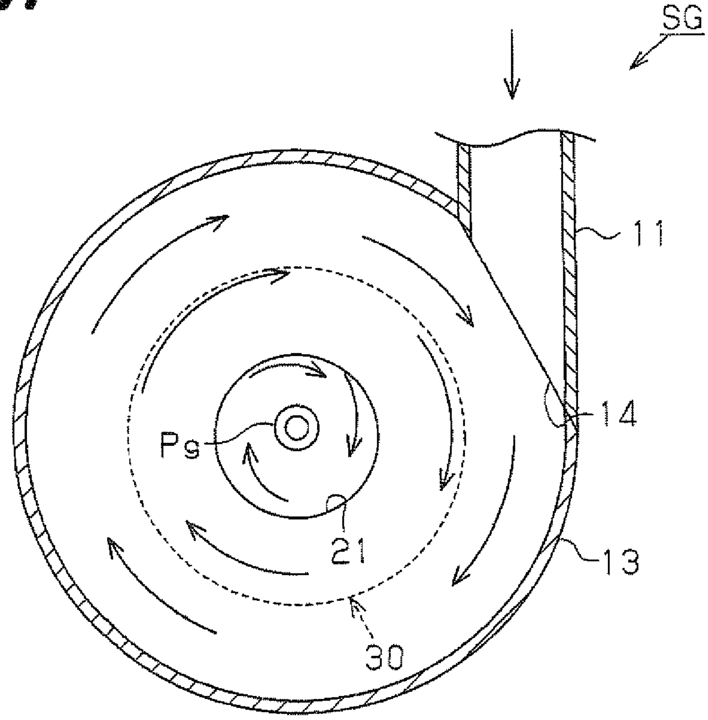


Fig.6(b)



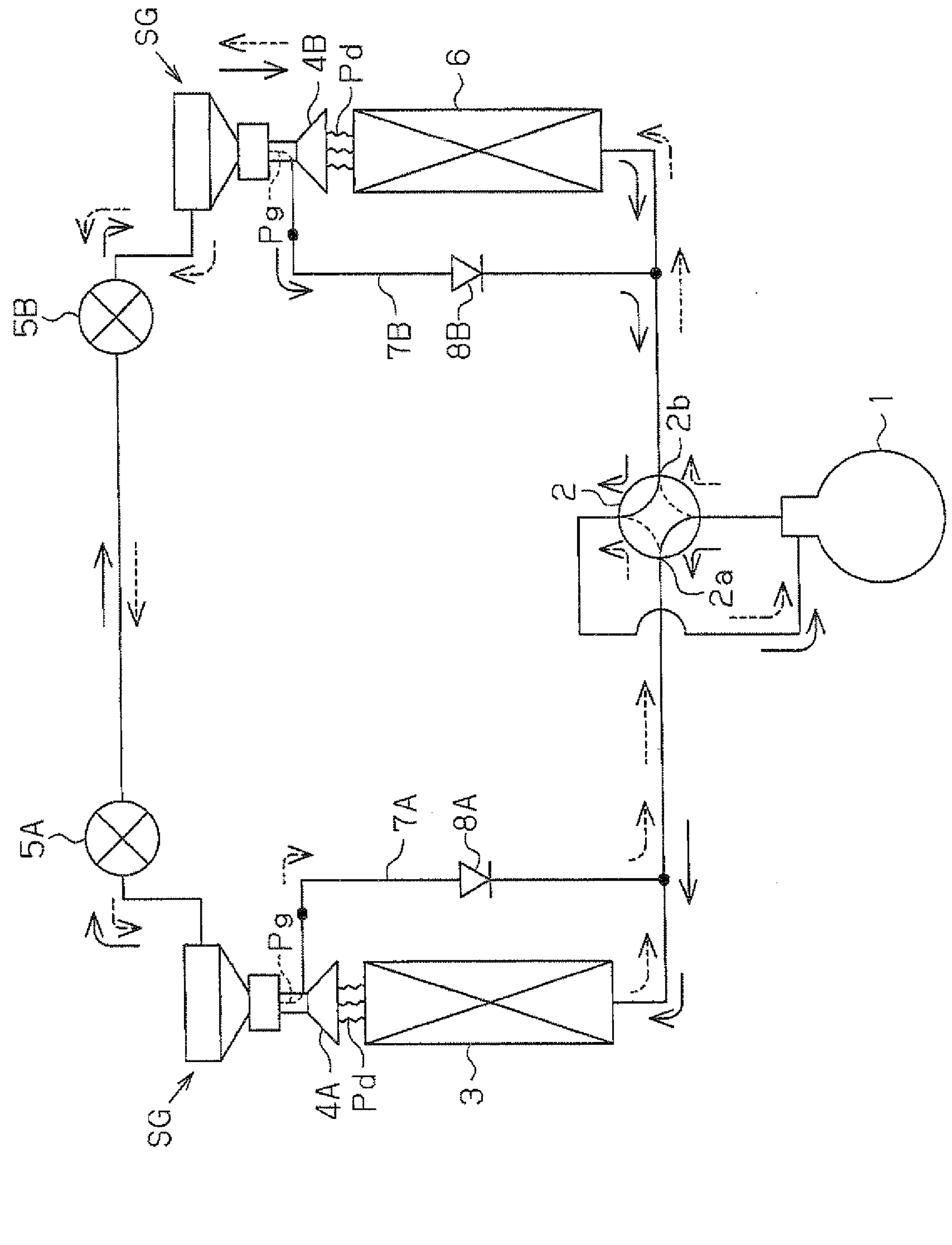


Fig.7

Fig.8(a)

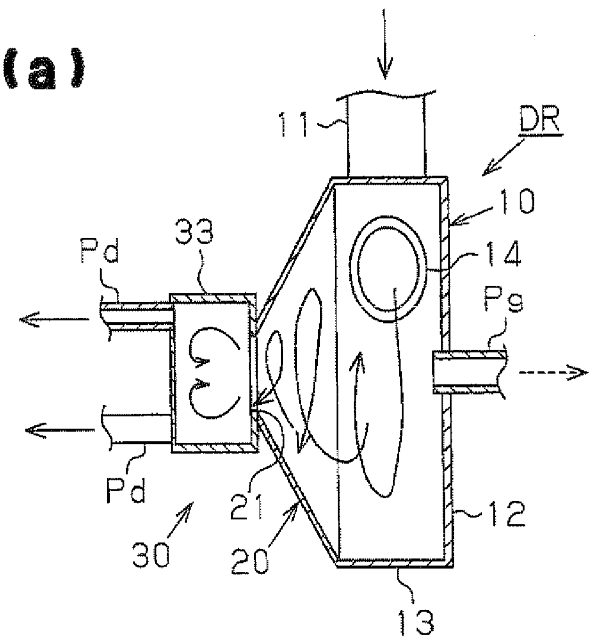


Fig.8(b)

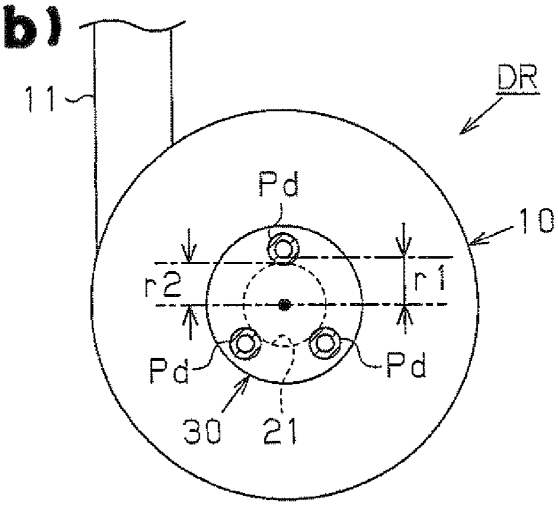
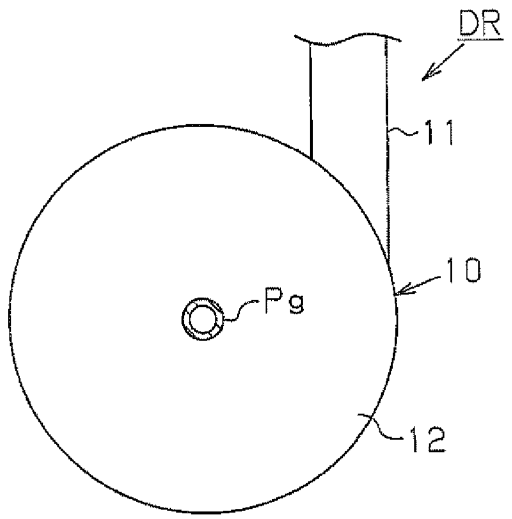


Fig.8(c)



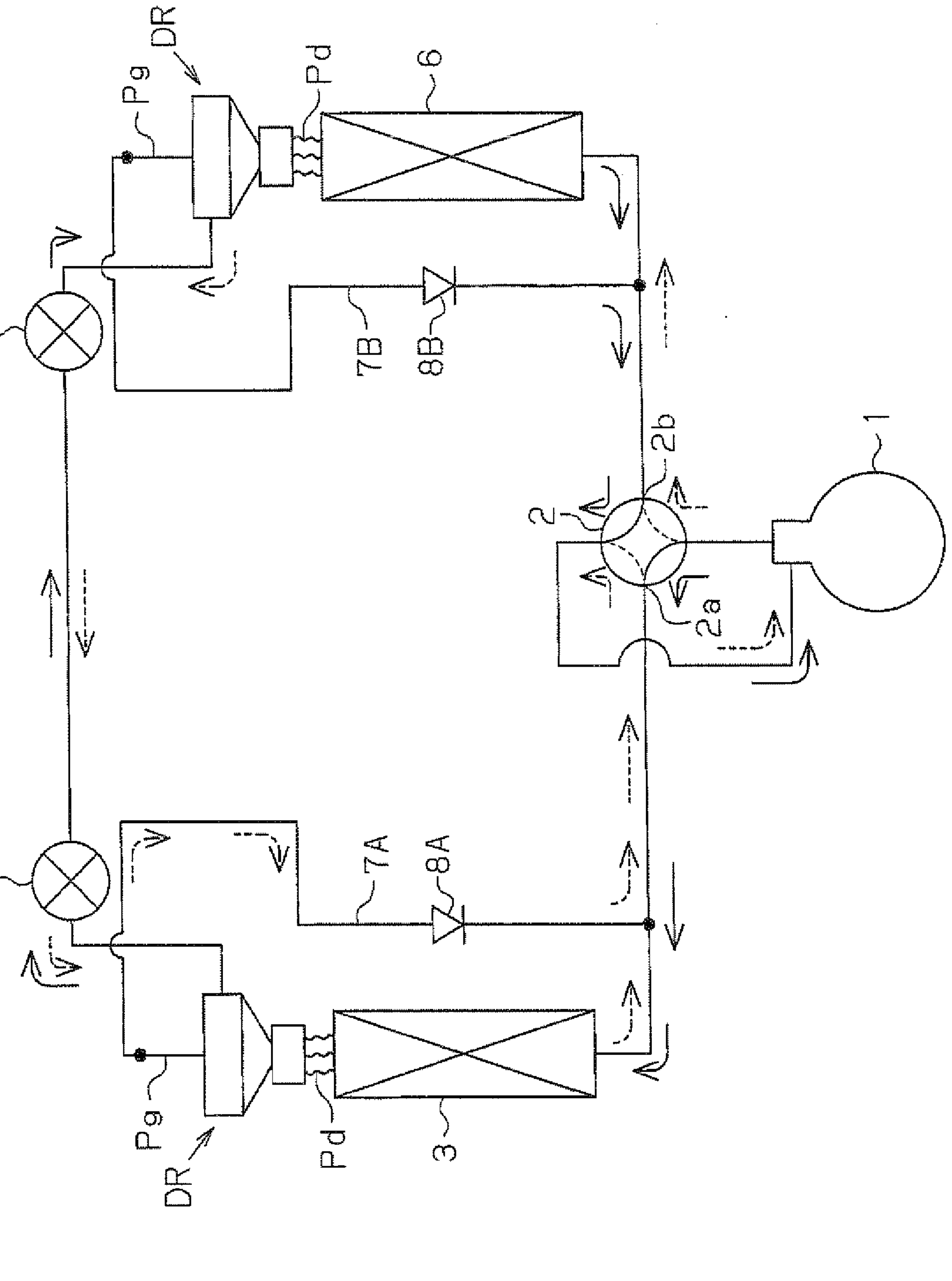


Fig.9

Fig.10(a)

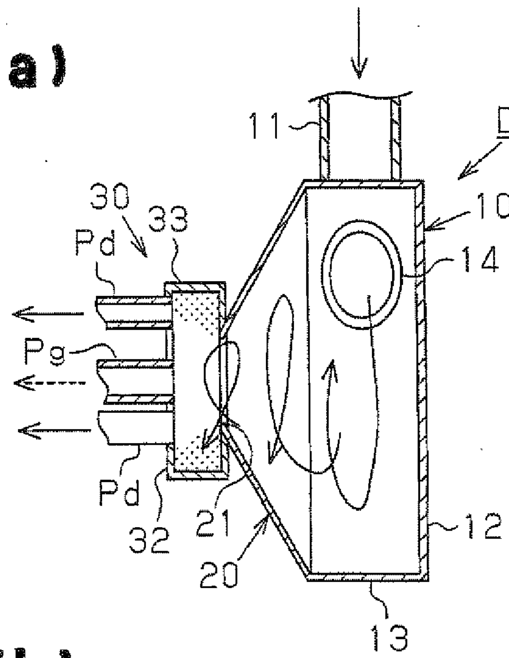


Fig.10(b)

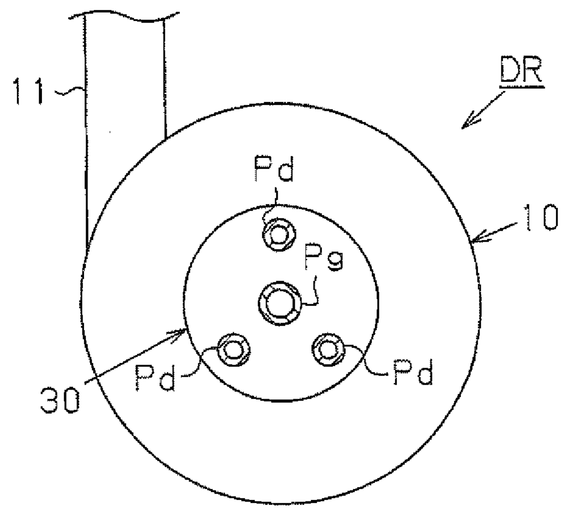
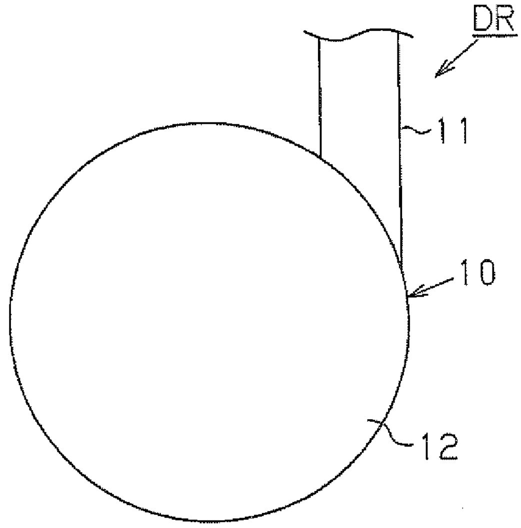


Fig.10(c)



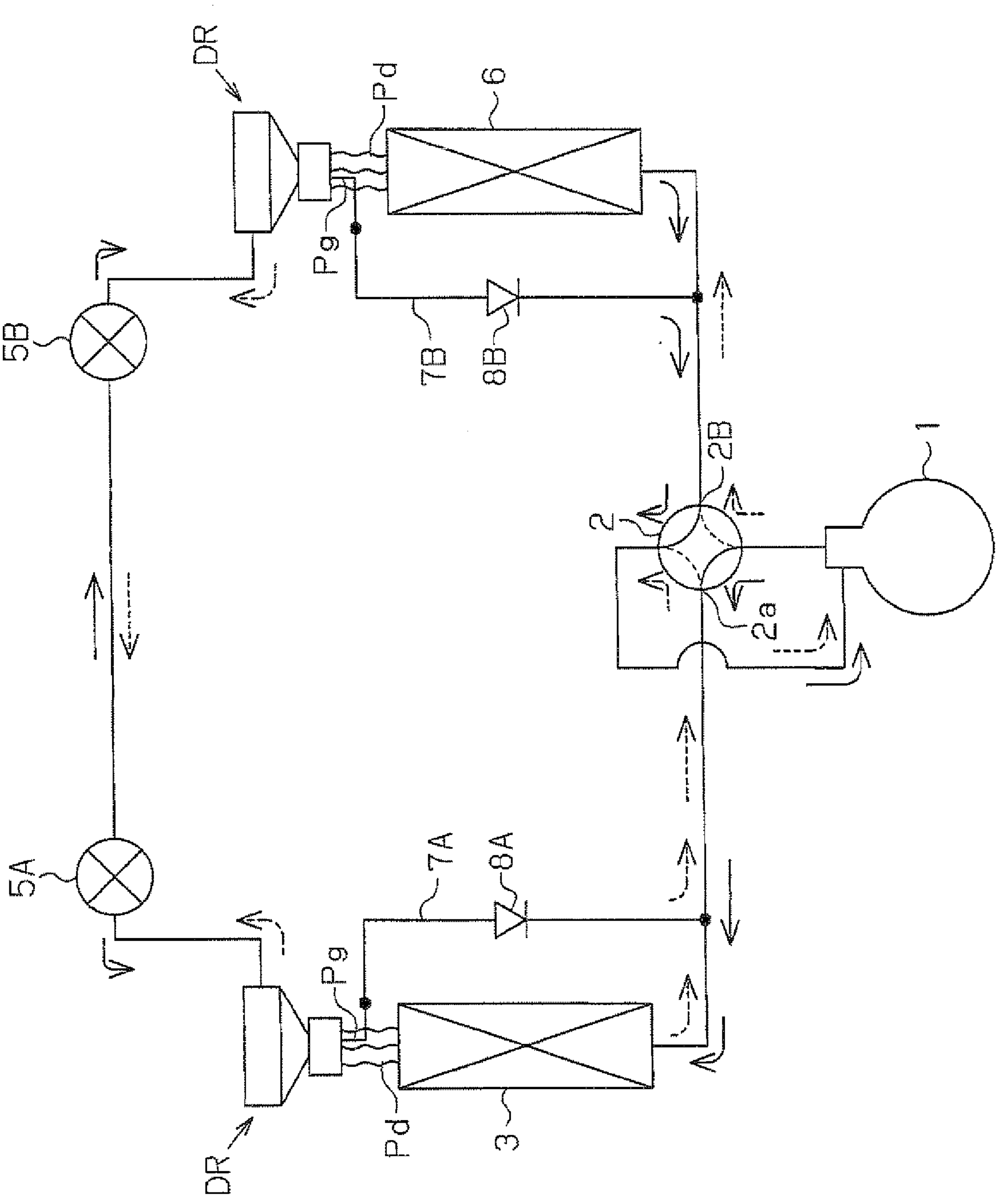


Fig.11

Fig.12(a)

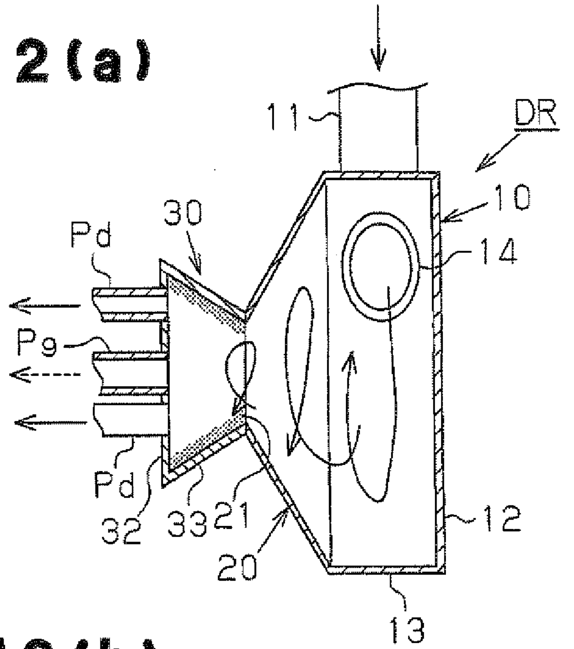


Fig.12(b)

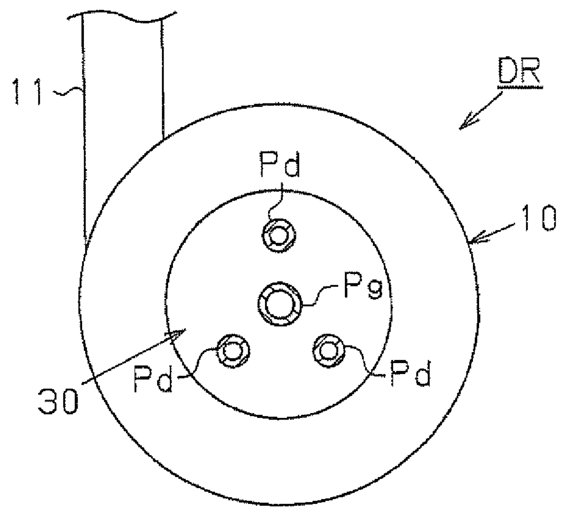


Fig.12(c)

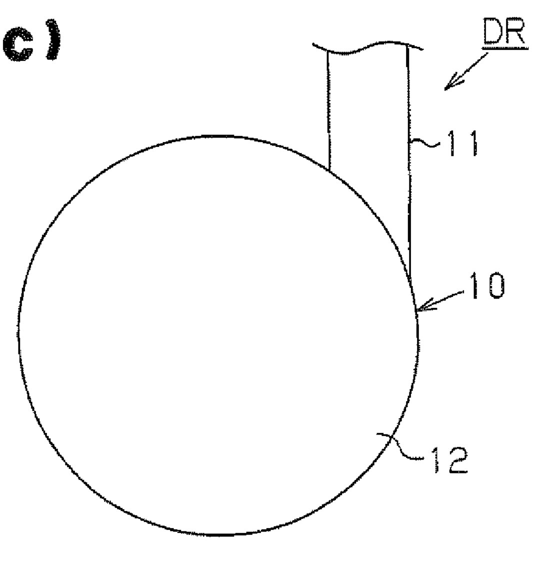


Fig.13(a)

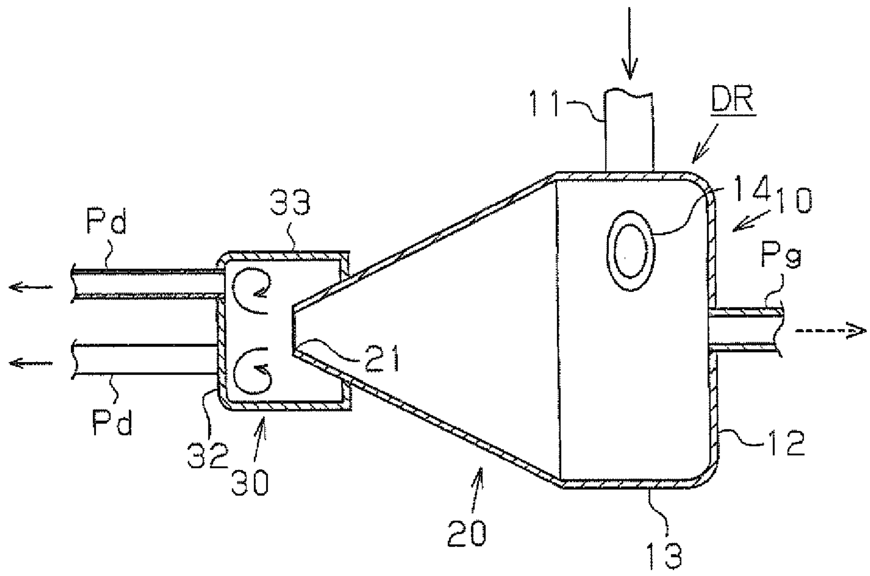


Fig.13(b)

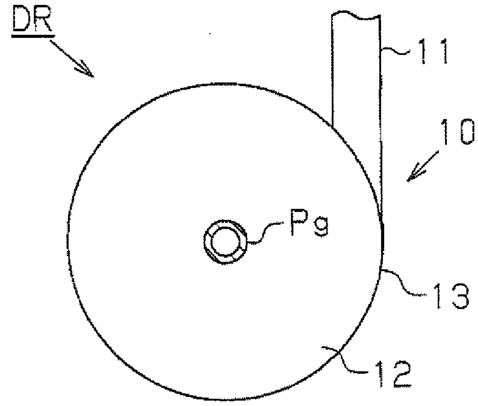


Fig.13(c)

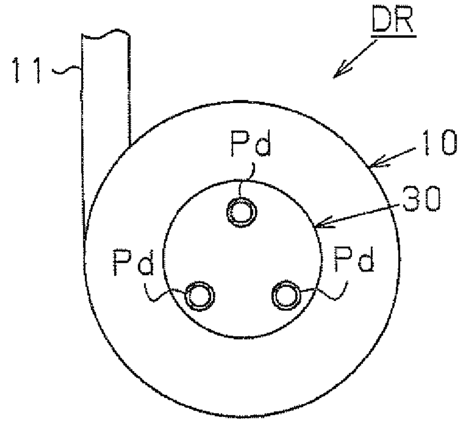


Fig.14

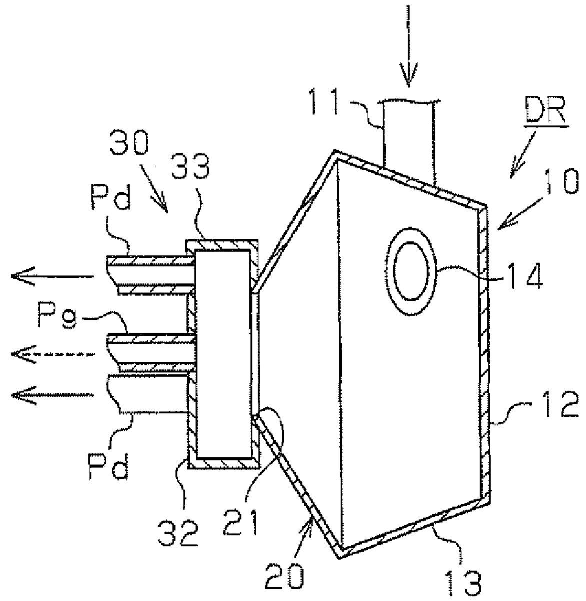

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Fig.15

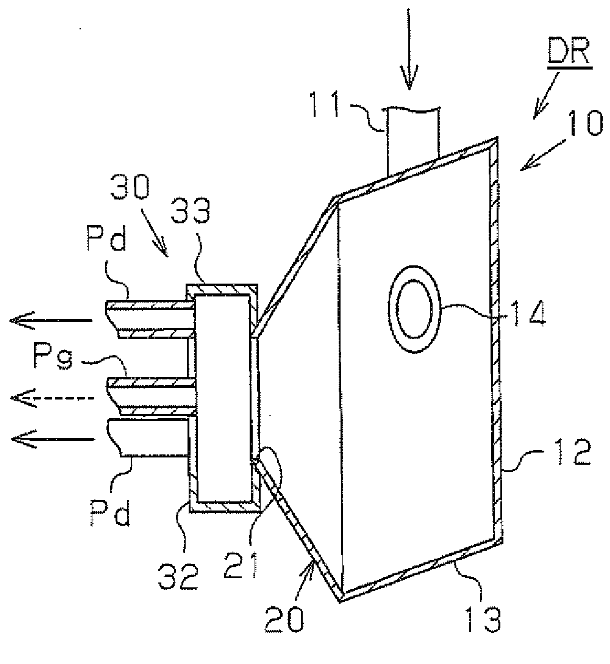
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Fig.16

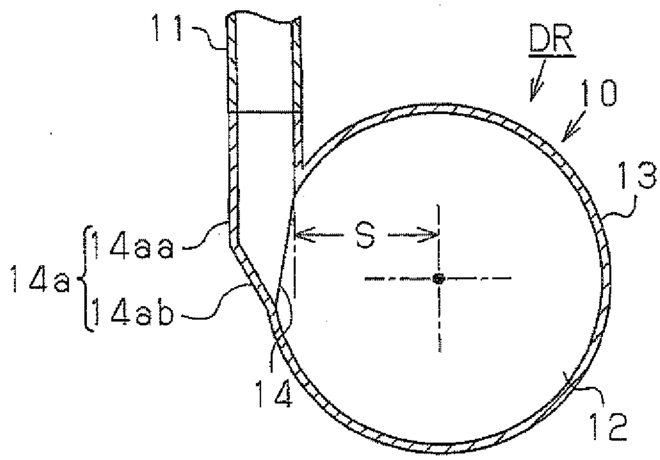

Fig.17

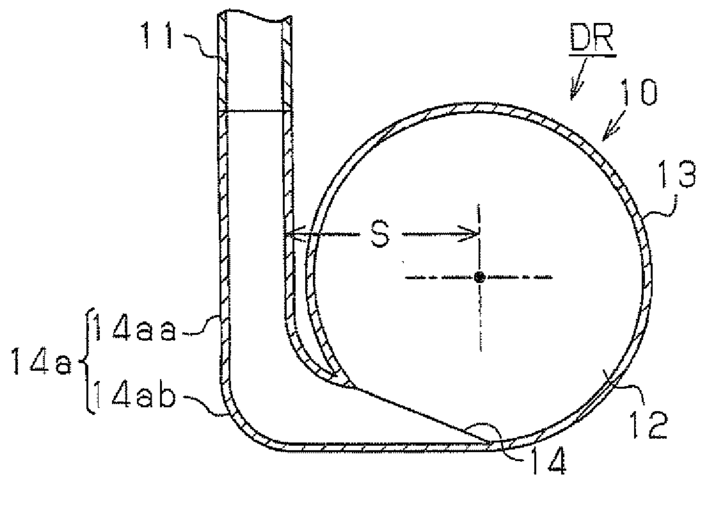

Fig.18

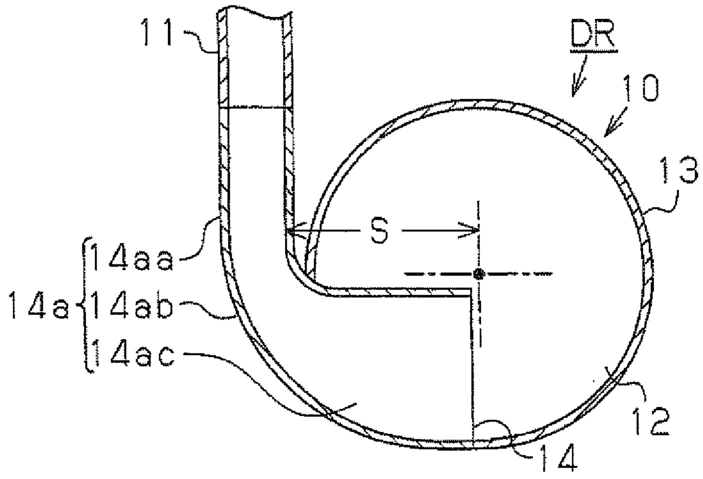
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Fig.19

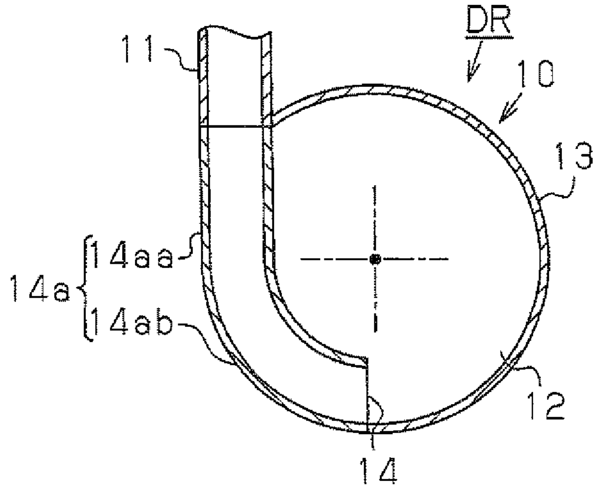
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Fig.20

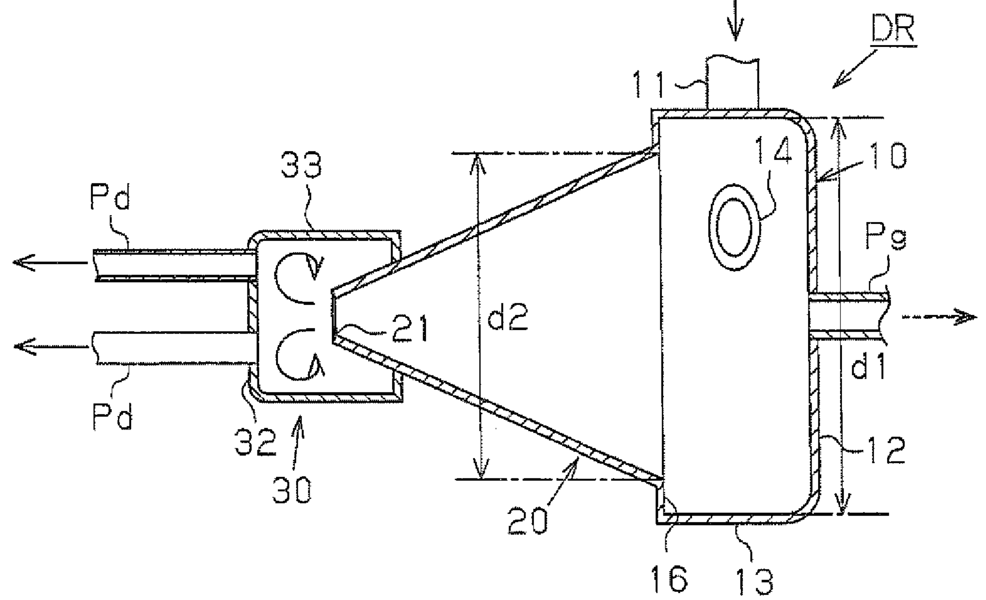
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Fig.21

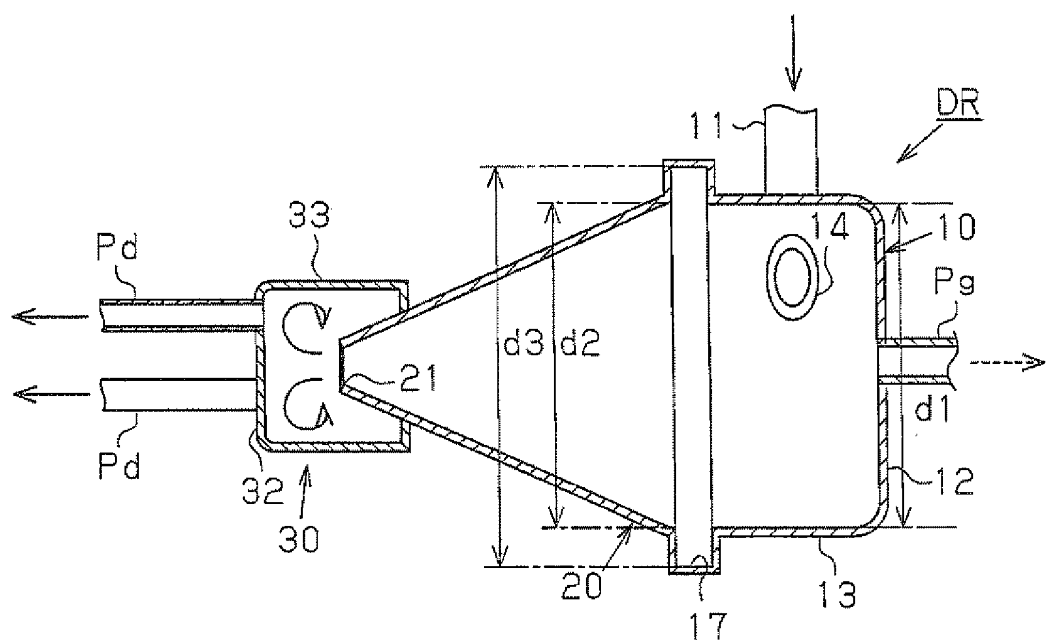
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Fig.22

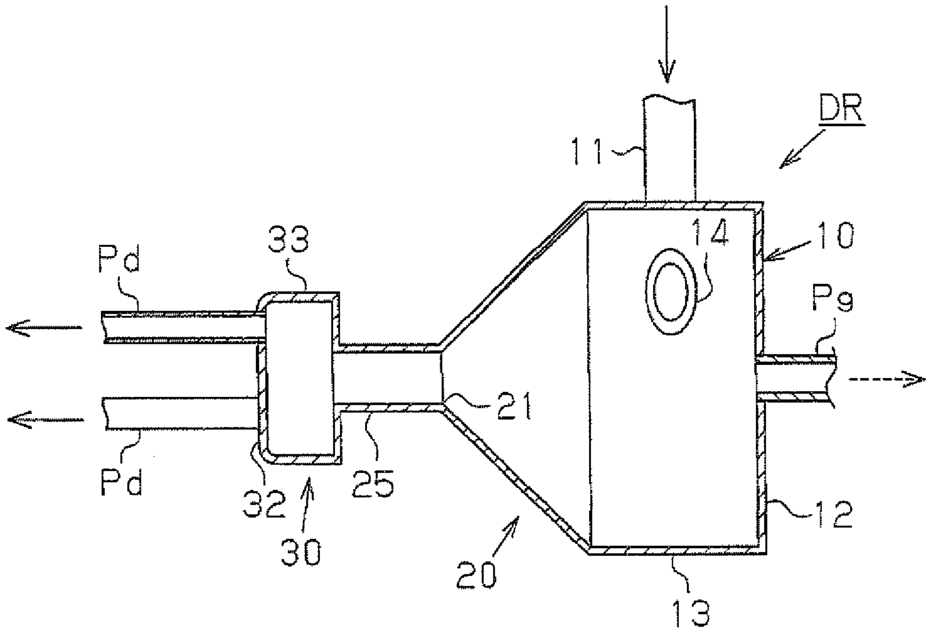
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Fig.23

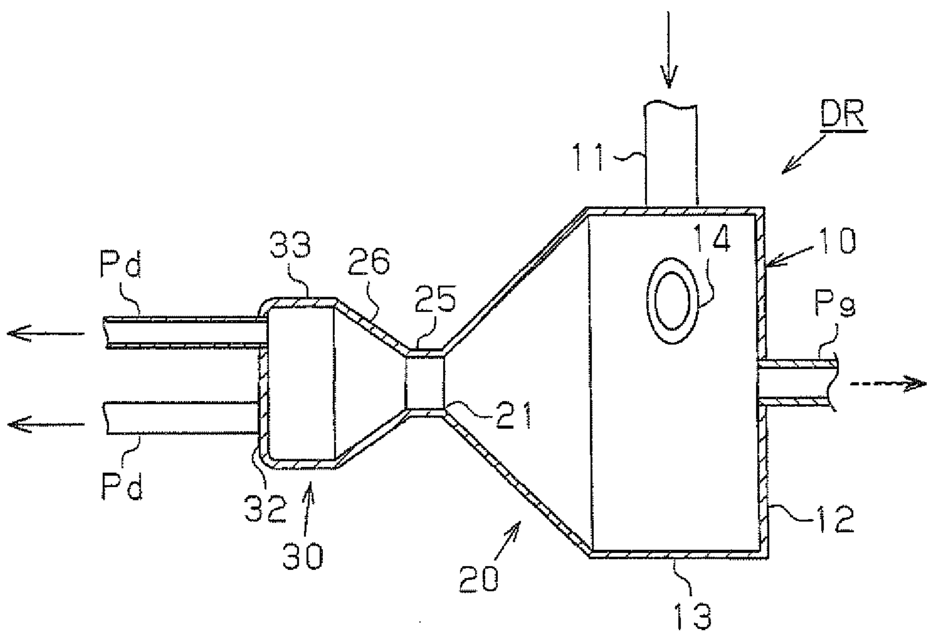
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Fig.24

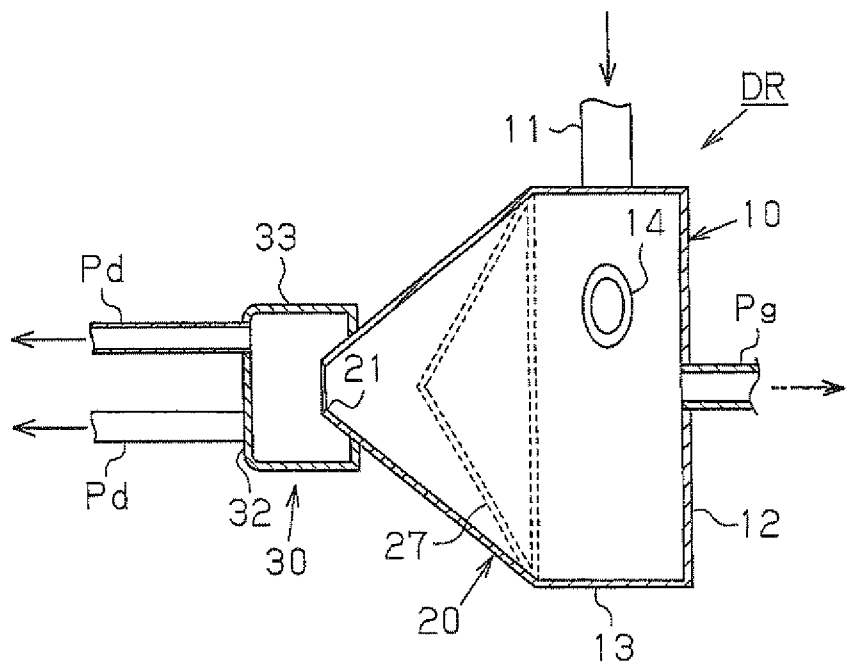

Fig.25(a)

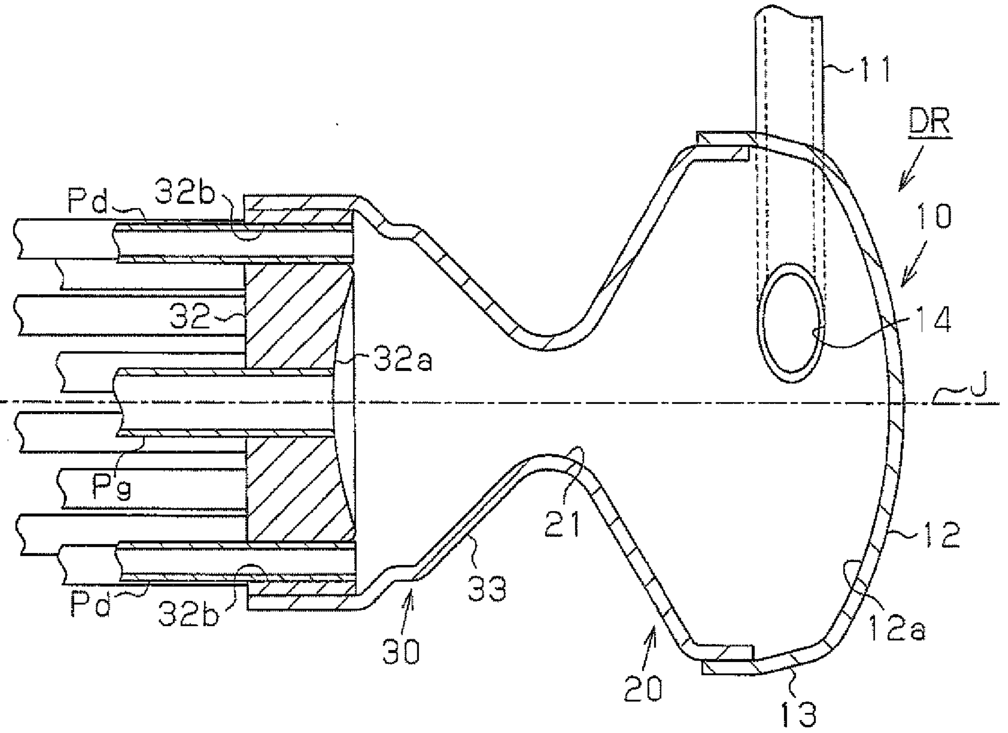

Fig.25(b)

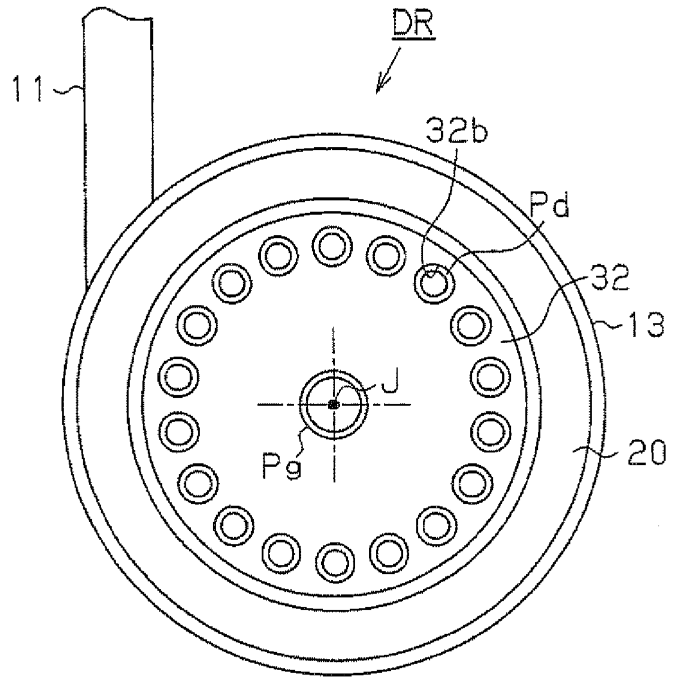

Fig.26

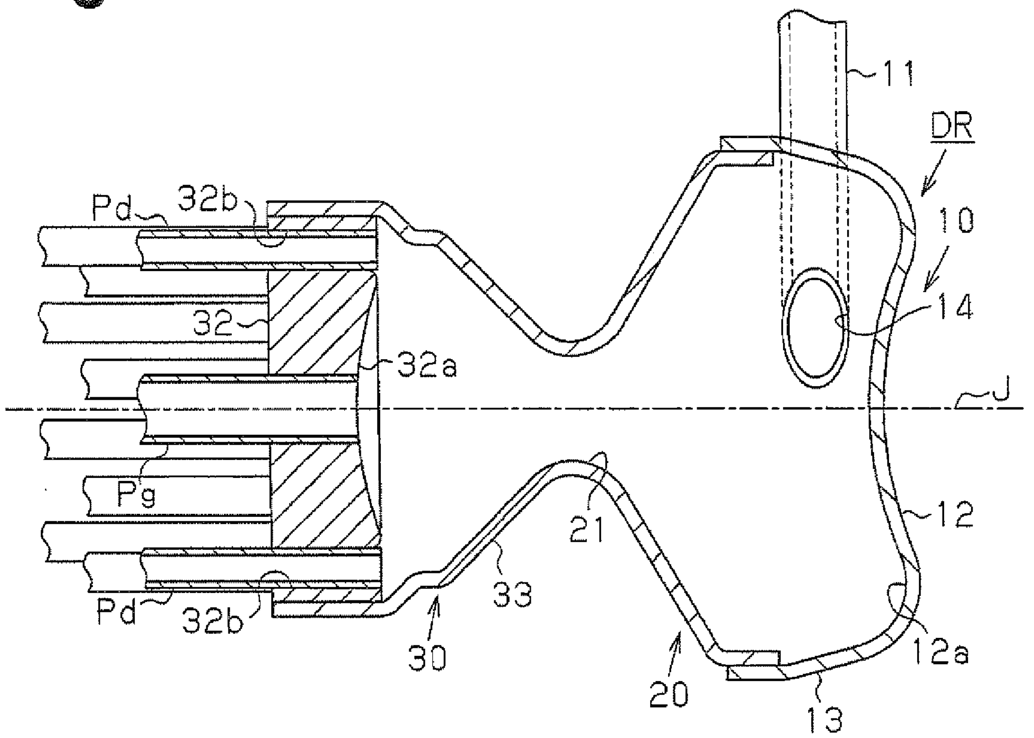
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Fig.27

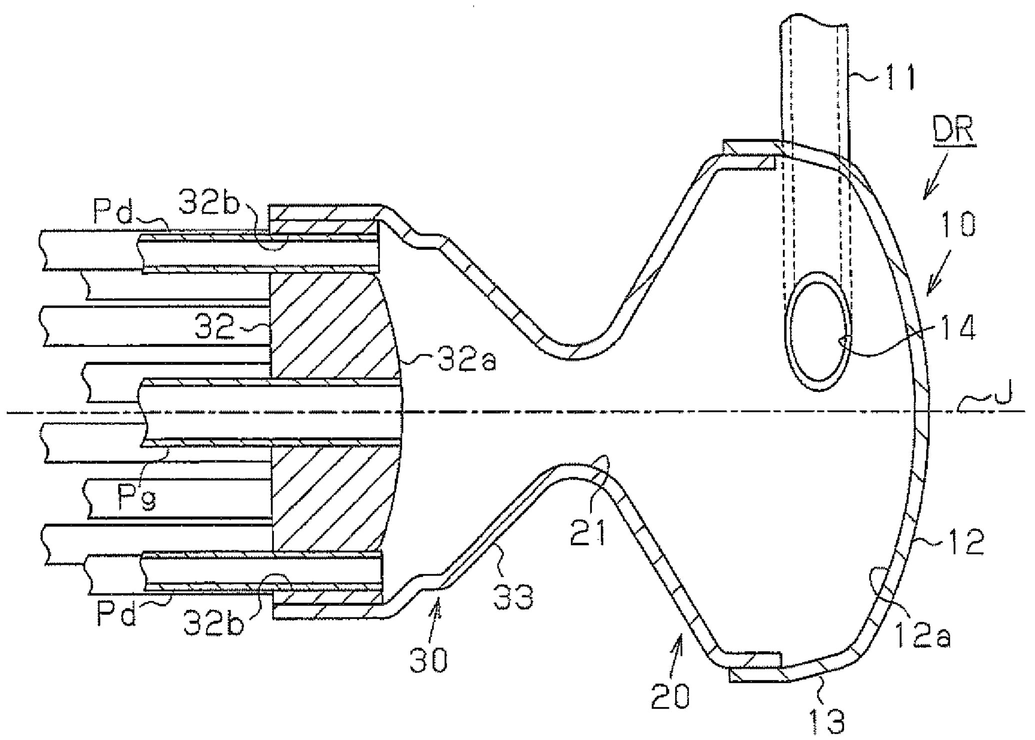
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Fig.28

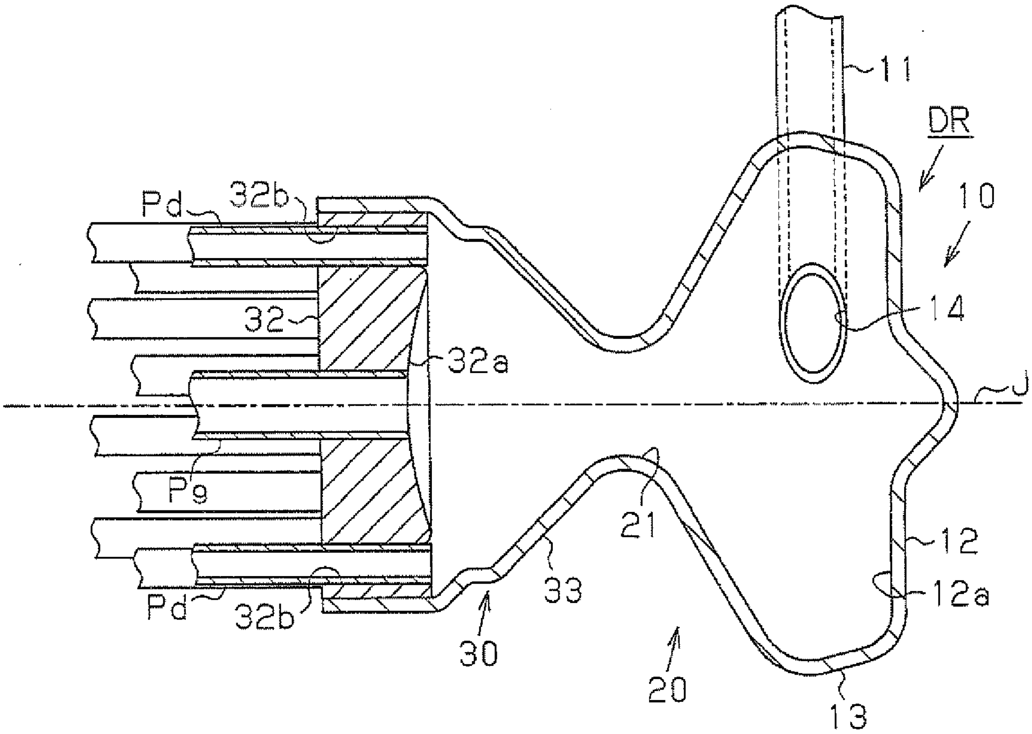
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Fig.29

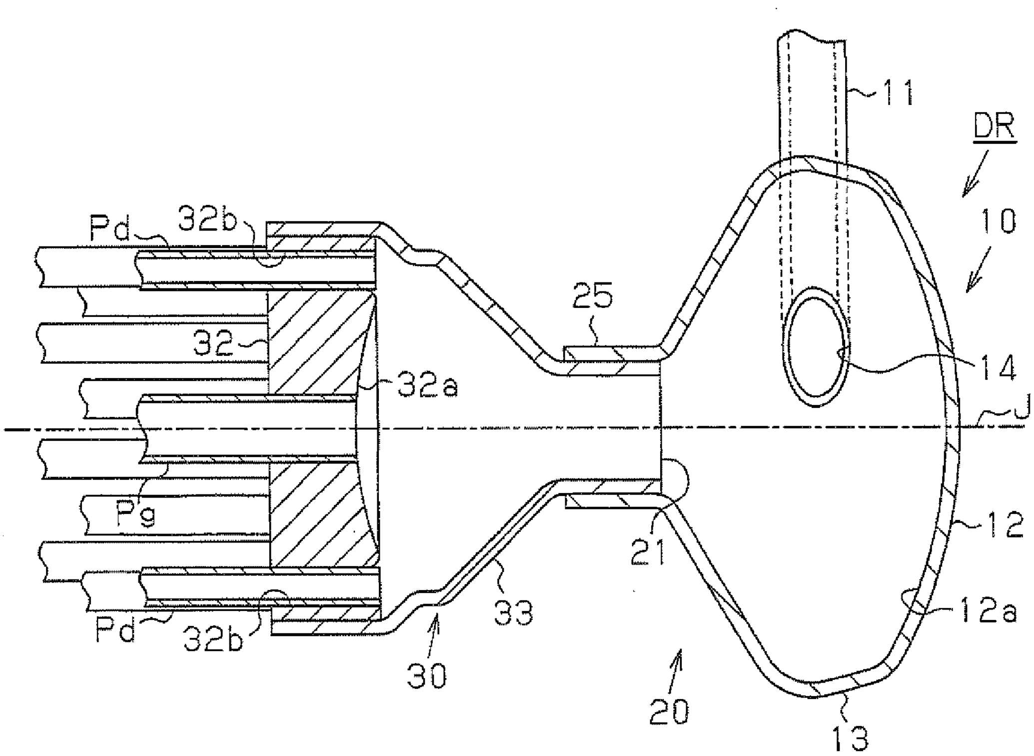
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Fig.30(a)

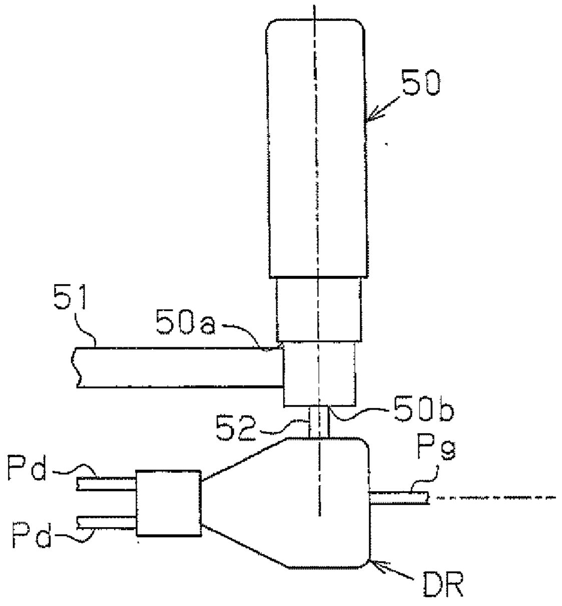


Fig.30(b)

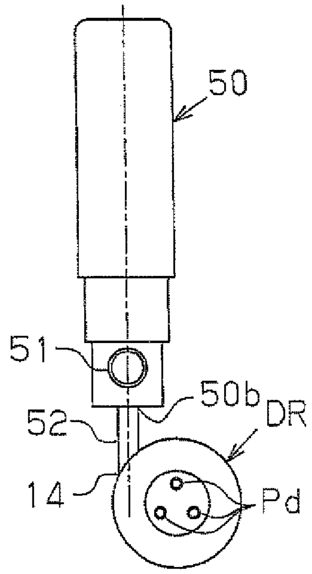


Fig.31(a)

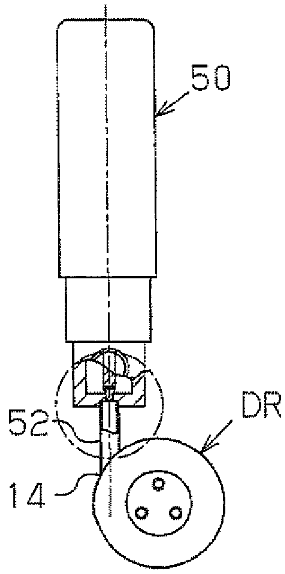


Fig.31(b)

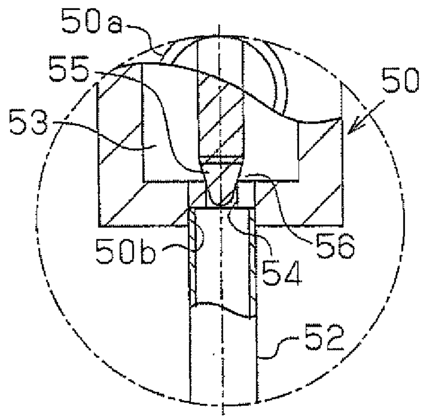
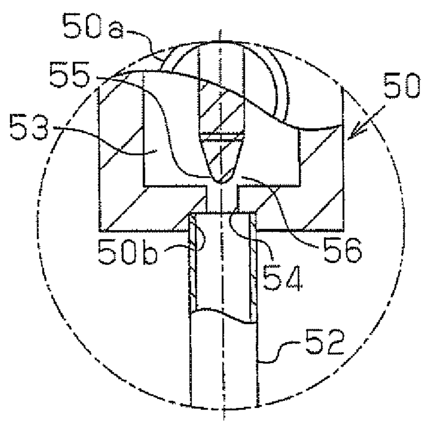


Fig.31(c)



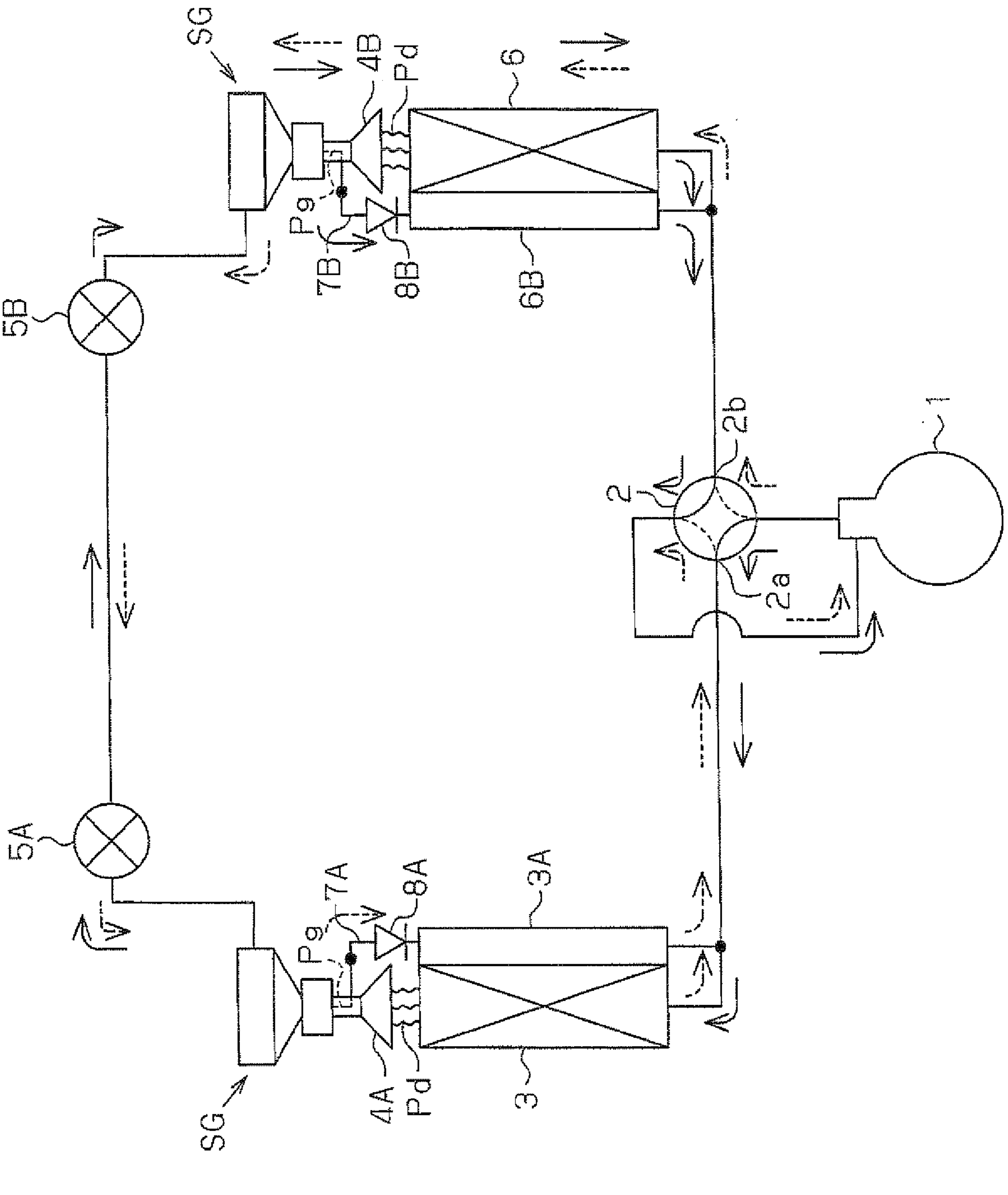


Fig. 32

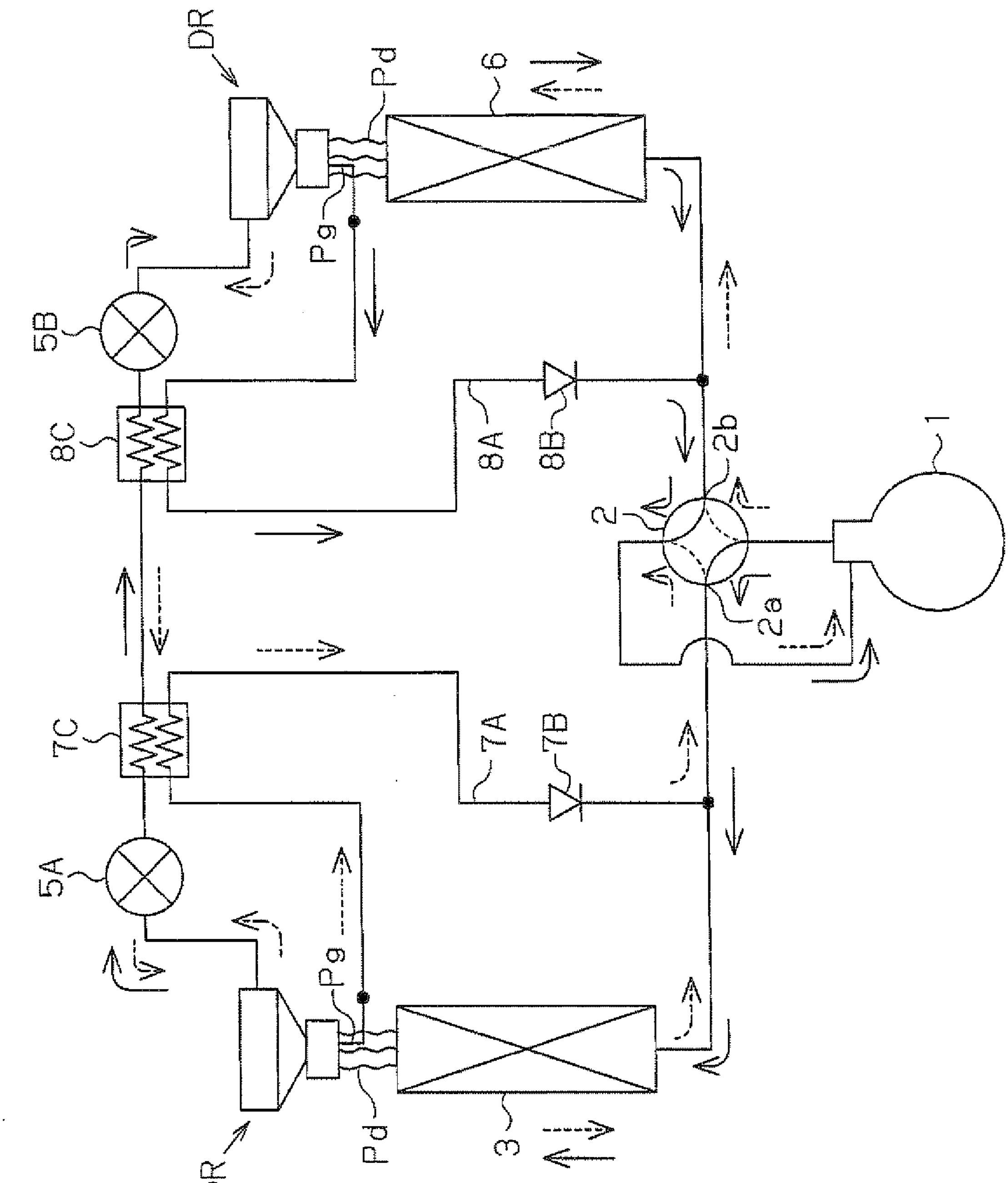


Fig.33

Fig.34(a)

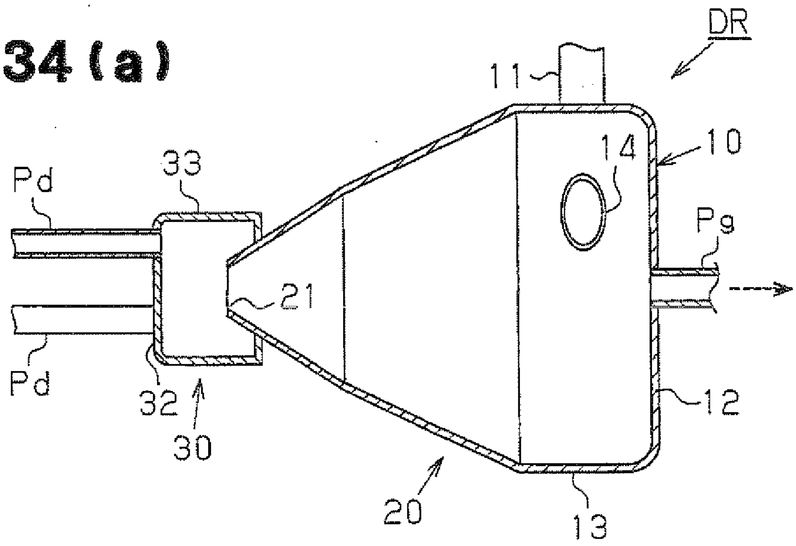


Fig.34(b)

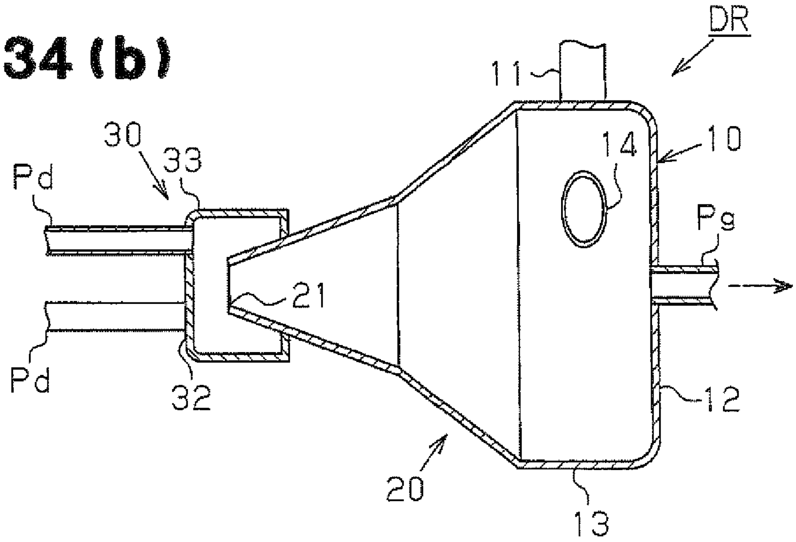


Fig.34(c)

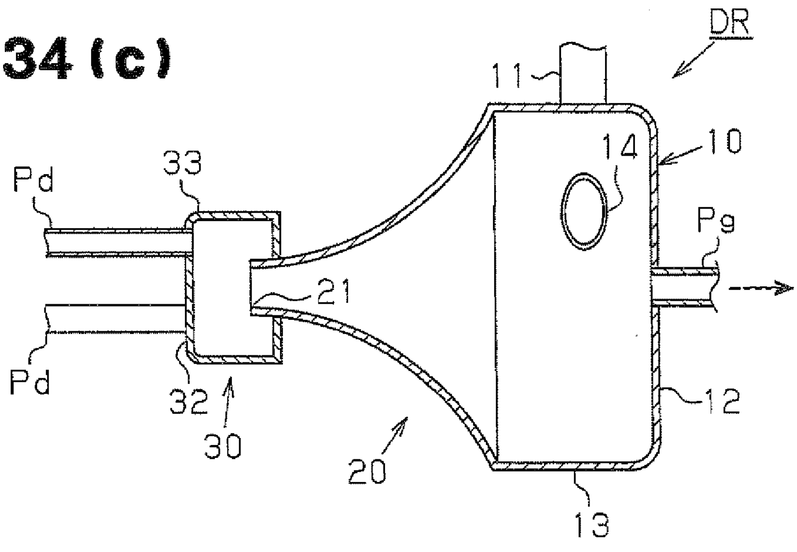


Fig.35

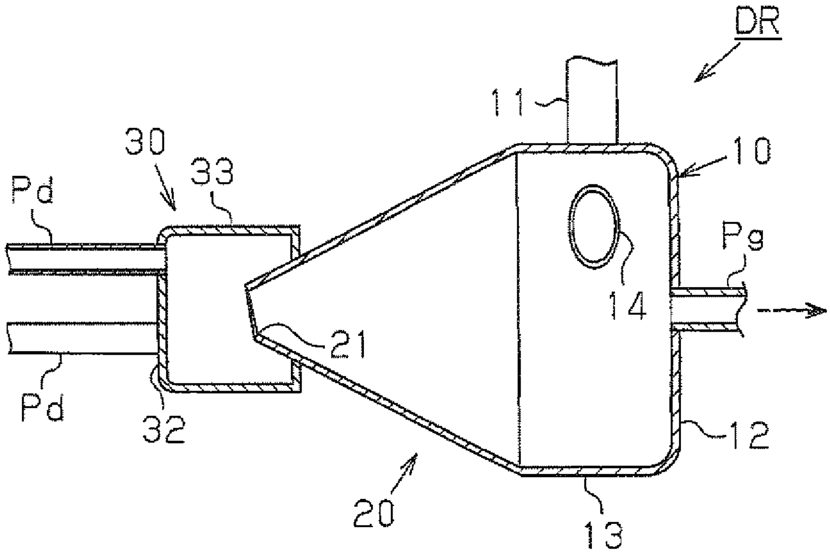


Fig.36(a)

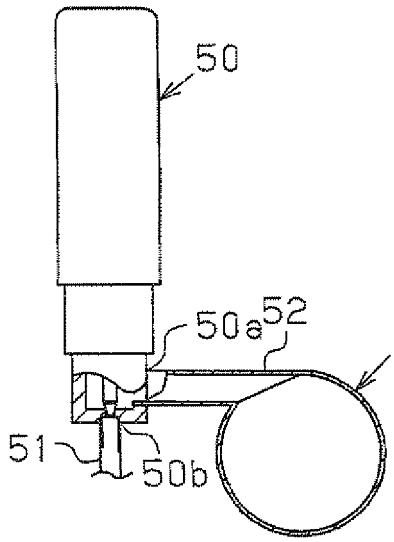


Fig.36(b)

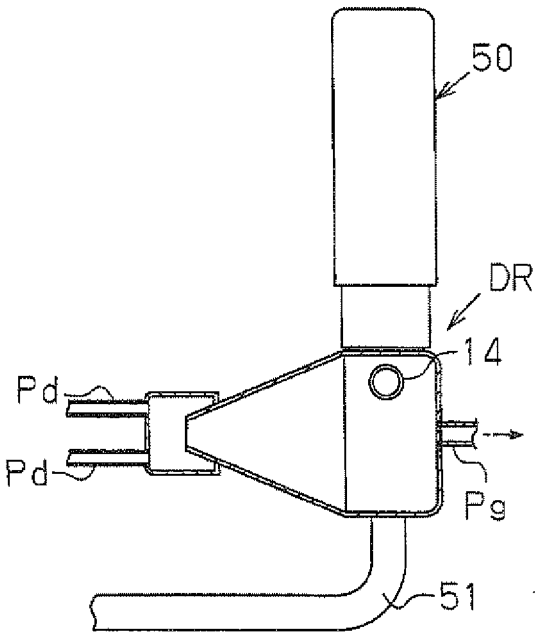


Fig.37

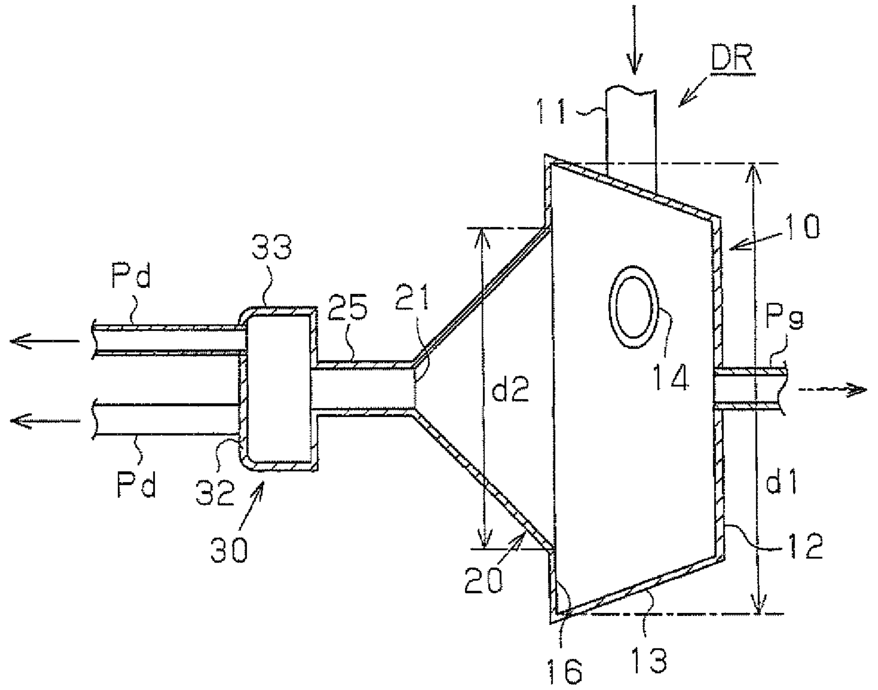

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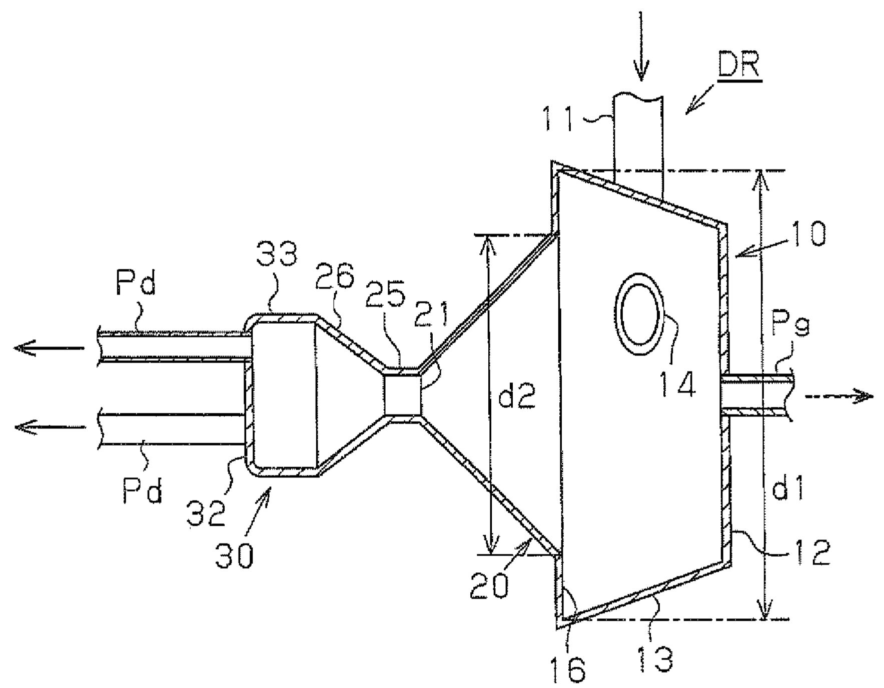
Fig.38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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/066320

A. CLASSIFICATION OF SUBJECT MATTER
F25B43/00(2006.01)i, *F25B41/04*(2006.01)i, *F25B41/06*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B43/00, F25B41/04, F25B41/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 59-119165 A (Hitachi, Ltd.), 10 July 1984 (10.07.1984), page 2, upper right column, line 8 to lower right column, line 2; fig. 1 to 5 (Family: none)	1-3,9,12,18, 24,25 15-17,19-23, 26-39
X Y	JP 53-59955 A (Danfoss A/S), 30 May 1978 (30.05.1978), page 4, upper left column, line 14 to lower right column, line 11; fig. 1 to 2 & US 4142380 A & GB 1591240 A & DE 2650935 A & FR 2370245 A & SE 7712544 A & ES 463917 A & CA 1067302 A & DK 493077 A & IT 1091950 A & SE 460984 B	1-3,9,12,24, 25 15-17,19-23, 26-39

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 December, 2010 (22.12.10)	11 January, 2011 (11.01.11)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/066320

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2000-249431 A (Mitsubishi Heavy Industries, Ltd.), 14 September 2000 (14.09.2000), paragraphs [0020] to [0021]; fig. 3 to 4 (Family: none)	15
Y	JP 4-90458 A (Mitsubishi Electric Corp.), 24 March 1992 (24.03.1992), page 2, lower right column, line 15 to page 3, upper left column, line 11; fig. 1 to 2 (Family: none)	16
Y	JP 10-62037 A (Mitsubishi Electric Corp.), 06 March 1998 (06.03.1998), paragraphs [0030] to [0031]; fig. 10 (Family: none)	17,19
Y	JP 2003-230850 A (Aisan Industry Co., Ltd.), 19 August 2003 (19.08.2003), paragraph [0016]; fig. 1 & US 2003/0150330 A1	20,21
Y	JP 2002-200402 A (Ryosaku FUJISATO), 16 July 2002 (16.07.2002), paragraph [0025]; fig. 2 (Family: none)	22,23
Y	JP 2004-263916 A (Kabushiki Kaisha Kobe Seisakusho), 24 September 2004 (24.09.2004), paragraph [0009]; fig. 2 (Family: none)	22,23
Y	JP 2008-196761 A (Daikin Industries, Ltd.), 28 August 2008 (28.08.2008), paragraphs [0075] to [0083]; fig. 5 to 7 (Family: none)	26-39
Y	JP 6-201225 A (Mitsubishi Heavy Industries, Ltd.), 19 July 1994 (19.07.1994), paragraphs [0007] to [0013]; fig. 1 (Family: none)	26-39
Y	WO 2007/55386 A1 (Nichirei Industries Co., Ltd.), 18 May 2007 (18.05.2007), paragraphs [0144] to [0147]; fig. 36 to 38 & CN 101310154 A	26-39
Y	JP 7-146035 A (Mitsubishi Electric Corp.), 06 June 1995 (06.06.1995), paragraphs [0094] to [0095]; fig. 22 (Family: none)	28

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/066320

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2008-96095 A (Daikin Industries, Ltd.), 24 April 2008 (24.04.2008), paragraphs [0039] to [0048]; fig. 1 & WO 2008/152760 A1	36
A	JP 2008-145030 A (Matsushita Electric Industrial Co., Ltd.), 26 June 2008 (26.06.2008), paragraphs [0024] to [0026]; fig. 3 to 4 (Family: none)	29,30

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/066320

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The search revealed that the matter common to the inventions in claims 1 - 39 is not a special technical feature within the meaning of PCT Rule 13.2, second sentence, since the matter is described in the document 1 (JP 59-119165 A) or the document 2 (JP 53-59955 A). It is optionally not inquired for the requirement of unity of invention with respect the inventions in claims 2, 3, 9, 12, 15 - 39.

(continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1 - 3, 9, 12, 15 - 39

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/066320

Continuation of Box No. III of continuation of first sheet(2)

However, with respect to the inventions in claims 4 - 8, 11, 13, 14, there is no other matter which is considered to be a special technical feature within the meaning of PCT Rule 13.2, second sentence and common to the inventions in the afore-said claims and the invention in claim 1, and therefore, any technical relationship within the meaning of PCT Rule 13 cannot be found among those different inventions.

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008196762 A **[0003]**