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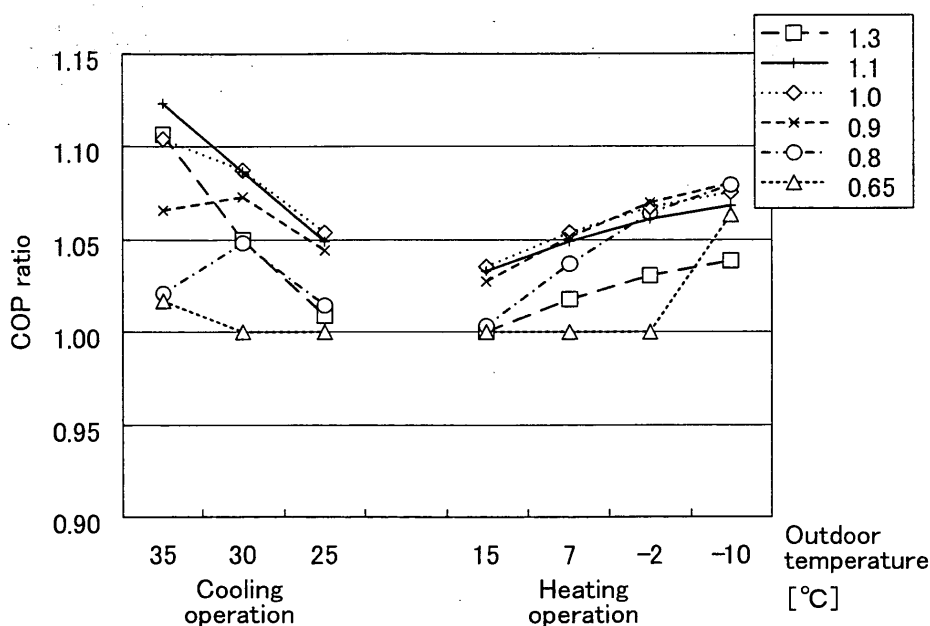
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(54) **REFRIGERATION DEVICE**

(57) A refrigerant circuit (10) includes a gas-liquid separator (15) and a compressor (30) including a low pressure side compression mechanism (34) and a high pressure side compression mechanism (35) connected to each other by means of a drive shaft (33). In the refrigerant circuit (10), a two-stage compression/two-stage

expansion refrigeration cycle is performed with CO₂ refrigerant utilized as that at its critical pressure. In the compressor (30), a volume ratio V₂/V₁ of the displacement volume V₂ of the second compression mechanism (35) to that V₁ of the first compression mechanism is set within a range between 0.8 and 1.3, both exclusive.

FIG. 4



Description

Technical Field

[0001] The present invention relates to a refrigerating apparatus including a refrigerant circuit including a gas-liquid separator for performing two-stage compression/two-stage expansion refrigeration cycle utilizing of CO₂ refrigerant at high pressure as that at its critical pressure.

Background Art

[0002] Conventionally, refrigerating apparatuses including a refrigerant circuit are widely applied to air conditioners and the like.

[0003] For example, Patent Document 1 discloses an air conditioner including a refrigerant circuit including a gas-liquid separator for performing a two-stage compression/two-stage expansion refrigeration cycle.

[0004] The refrigerant circuit of this air conditioner includes a compressor, a first heat exchanger, a first expansion valve, a gas-liquid separator, a second expansion valve, and a second heat exchanger. The compressor is of two-stage compression type in which a low pressure side compression mechanism and a high pressure side compression mechanism are connected by means of a drive shaft. The gas-liquid separator is so composed to separate intermediate-pressure refrigerant in a gas-liquid two-phase state into liquid refrigerant and gas refrigerant.

[0005] In a cooling operation of the air conditioner, refrigerant discharged from the compressor flows into the first heat exchanger. In the first heat exchanger, the refrigerant release heat to the air. The refrigerant having passed through the first heat exchanger is reduced in pressure up to intermediate pressure through the first expansion valve and flows then into the gas-liquid separator. In the gas-liquid separator, the intermediate-pressure refrigerant in the gas-liquid two-phase state is separated into the gas refrigerant and the liquid refrigerant. The liquid refrigerant thus separated in the gas-liquid separator is reduced in pressure up to low pressure through the second expansion valve and flows then into the second heat exchanger. In the second heat exchanger, the refrigerant absorbs heat from the air to be evaporated. In this way, the indoor cooling is performed.

[0006] The refrigerant having passed through the second heat exchanger is sucked into the compressor to be compressed up to intermediate pressure in the low pressure side compression mechanism. The refrigerant discharged from the low pressure side compression mechanism is mixed with the gas refrigerant separated in the gas-liquid separator. In other words, the air conditioner performs generally-called intermediate pressure gas injection in which the intermediate-pressure gas refrigerant is mixed with the refrigerant discharged from the low pressure side compression mechanism. Thereafter, the thus

mixed refrigerant is compressed up to high pressure in the high pressure side compression mechanism and is then discharged from the compressor again.

[0007] As described above, the air conditioner of Patent Document 1 performs the intermediate pressure gas injection to lower the temperature of the refrigerant discharged from the compressor for reducing the power required for driving the compressor, thereby increasing the COP (coefficient of performance) of the air conditioner.

[0008] Patent Document 2 discloses an air conditioner in which the aforementioned intermediate pressure gas injection is performed with CO₂ refrigerant filled in a refrigerant circuit. This air conditioner performs a generally-called supercritical cycle in which the refrigerant discharged from the compressor is compressed over its critical pressure.

Patent Document 1: Japanese Unexamined Patent Application Publication 7-110167

Patent Document 2: Japanese Unexamined Patent Application Publication 2001-241797

Disclosure of the Invention

Problems that the Invention is to Solve

[0009] In the air conditioner as disclosed in Patent Document 1, the volume (displacement volume) of each compression mechanism of the two-stage compression type compressor is so designed to attain efficient two-stage compression. On the other hand, in the supercritical cycle using CO₂ as the refrigerant of such an air conditioner, the refrigerant after being compressed up to its supercritical pressure and releasing heat in an heat exchanger may be at the supercritical pressure yet in the gas-liquid separator. The refrigerant at supercritical pressure (in the critical state) in the gas-liquid separator is difficult to be separated into the gas refrigerant and the liquid refrigerant. This inhibits sending of only the gas refrigerant to the intermediate-pressure refrigerant in the compressor to inhibit the aforementioned intermediate pressure gas injection. Accordingly, desired effects by the intermediate pressure gas injection cannot be attained to invite lowering of the COP of the air conditioner.

[0010] The present invention has been made in view of the foregoing and has its object of enabling operation at an optimal COP in a refrigerating apparatus performing two-stage compression/two-stage expansion refrigeration cycle using CO₂ refrigerant.

Means for Solving the Problems

[0011] A first aspect of the present invention premises a refrigerating apparatus including a refrigerant circuit for performing a two-stage compression/two-stage expansion refrigeration cycle in which CO₂ refrigerant at high pressure is utilized as that at its critical pressure, the refrigerant circuit including: a compressor including a low

pressure side compression mechanism and a high pressure side compression mechanism connected to each other by means of a drive shaft; and a gas-liquid separator for separating refrigerant at intermediate pressure into gas refrigerant and liquid refrigerant. In this refrigerating apparatus, a volume ratio of a displacement volume of the high pressure side compression mechanism to that of the low pressure side compression mechanism falls in a range between 0.8 and 1.3, both exclusive.

[0012] The refrigerant circuit (10) in the first aspect is filled with CO₂ refrigerant. Further, the compressor (30) including the low pressure side compression mechanism (34) and the high pressure side compression mechanism (35) is provided in the refrigerant circuit (10). In the refrigerant circuit (10), the following two-stage compression/two-stage expansion refrigeration cycle is performed.

[0013] The refrigerant compressed up to its critical pressure in the high pressure side compression mechanism (35) releases heat in, for example, an indoor heat exchanger, is reduced in pressure up to intermediate pressure, and flows then into the gas-liquid separator (15). In the gas-liquid separator (15), the intermediate-pressure refrigerant is separated into the gas refrigerant and the liquid refrigerant. The liquid refrigerant is reduced in pressure up to low pressure, is evaporated in, for example, an outdoor heat exchanger, and is then sucked into the low pressure side compression mechanism (34). This refrigerant is compressed up to intermediate pressure in the low pressure side compression mechanism (34). Then, the gas refrigerant separated in the liquid-gas separator (15) is introduced into this refrigerant. Thus, the aforementioned intermediate pressure gas injection is performed. Thereafter, the refrigerant is compressed up to high pressure (critical pressure) in the high pressure side compression mechanism (35).

[0014] In the case where the two-stage compression/two-stage expansion refrigeration cycle is performed with the use of CO₂ refrigerant in this way, the intermediate-pressure refrigerant in the gas-liquid separator may reach its critical pressure in the conventional refrigerating apparatus. If so, the refrigerant in the gas-liquid separator cannot be separated into the gas refrigerant and the liquid refrigerant to inhibit desired intermediate pressure gas injection. To tackle this problem, the volume ratio of the high pressure side compression mechanism (35) to the low pressure side compression mechanism (34) is set greater than 0.8. When the volume ratio is set equal to or smaller than 0.8, the displacement volume of the high pressure side compression mechanism (35) becomes relatively smaller than that of the low pressure side compression mechanism (34), thereby increasing the pressure of the intermediate-pressure refrigerant to invite an increase in pressure of the refrigerant in the gas-liquid separator (15) over its critical pressure. In contrast, in this aspect of the present invention, in which the volume ratio is set greater than 0.8, the refrigerant in the gas-liquid separator (15) can be suppressed

at its subcritical pressure. Hence, in this aspect, the refrigerant in the gas-liquid separator (15) is definitely separated into the gas refrigerant and the liquid refrigerant to attain desired effects by the intermediate pressure gas injection.

[0015] When assumed that the volume ratio is set equal to or greater than 1.3, the displacement volume of the high pressure side compression mechanism (35) is relatively greater than that of the low pressure side compression mechanism (34). As a result, the amount of the refrigerant sucked in the high pressure side compression mechanism (35) is secured insufficiently to invite lowering of the compression efficiency of the compressor (30). In contrast, this aspect of the present invention sets the volume ratio to be smaller than 1.3 to secure a sufficient amount of the refrigerant sucked in the high pressure side compression mechanism (35), with a result that the refrigerant can be compressed in two stages efficiently.

[0016] Referring to a second aspect of the present invention, in the first aspect, the volume ratio falls in a range between 0.9 and 1.1, both inclusive.

[0017] In the second aspect of the present invention, the volume ratio of the displacement volume of the high pressure side compression mechanism (35) to that of the low pressure side compression mechanism (34) is set in the range between 0.9 and 1.1, both inclusive. The volume ratio exceeding 0.9 definitely makes the refrigerant in the gas-liquid separator (15) reach its critical pressure. While, the volume ratio not exceeding 1.1 attains further efficient two-stage compression of the refrigerant.

[0018] Referring to a third aspect of the present invention, in the second aspect, the volume ratio is 1.0.

[0019] In the third aspect of the present invention, the volume of the low pressure side compression mechanism (34) and that of the high pressure side compression mechanism (35) are set equal to each other.

[0020] Referring to a fourth aspect of the present invention, in any one of the first to third aspects, the low pressure side compression mechanism and the high pressure side compression mechanism are rotary compression mechanisms.

[0021] In the fourth aspect of the present invention, the compressor (30) is so composed that the low pressure side compression mechanism (34) and the high pressure side compression mechanism (35) are connected to each other by means of the drive shaft (33).

Effects of the Invention

[0022] In the present invention, the volume ratio of the high pressure side compression mechanism (35) to the low pressure side compression mechanism (34) is set in the range between 0.8 and 1.3, both exclusive. The volume ratio over 0.8 reduces the pressure of the refrigerant in the gas-liquid separator (15) lower than its critical pressure. Accordingly, desired intermediate pressure gas injection can be performed in the refrigerant circuit (10) to increase the COP of the refrigerating apparatus in the

present invention. On the other hand, the volume ratio below 1.3 invites no lowering of the compression efficiency accompanied by insufficiency of the amount of the refrigerant sucked in the high pressure side compression mechanism (35), thereby attaining two-stage compression of the refrigerant. Hence, the COP of the refrigerating apparatus can be increased further in the present invention.

[0023] Particularly, the volume ratio of the high pressure side compression mechanism (35) to the low pressure side compression mechanism (34) is set in the range between 0.9 and 1.1, both inclusive, in the second aspect of the present invention. In other words, the volume ratio of the high pressure side compression mechanism (35) to the low pressure side compression mechanism (34) is set in further optimum range. Hence, the COP of the refrigerating apparatus can be increased further in this aspect.

[0024] In the third aspect of the present invention, the volume ratio of the low pressure side compression mechanism (34) to the volume ratio of the high pressure side compression mechanism (35) are set equal to each other. Accordingly, the low pressure side compression mechanism (34) and the high pressure side compression mechanism (35) can be structured according to the same specification in their compression mechanism, thereby contemplating cost reduction and simplification of the compressor (30).

[0025] According to the fourth aspect of the present invention, desired intermediate pressure gas injection is performed in the refrigerating apparatus including the compressor (30) including the two rotary compression mechanisms to thus increase the COP thereof.

Brief Description of the Drawings

[0026]

[FIG. 1] FIG. 1 is a piping system diagram of a refrigerant circuit in an air conditioner in accordance with one embodiment.

[FIG. 2] FIG. 2 is a piping system diagram for explaining refrigerant flow in a heating operation of the air conditioner.

[FIG. 3] FIG. 3 is a piping system diagram for explaining refrigerant flow in a cooling operation of the air conditioner.

[FIG. 4] FIG. 4 is a graph showing the relationship between the COP and the volume ratio of a high pressure side compression mechanism to a low pressure side compression mechanism.

Index of Reference Numerals

[0027]

1 air conditioner
10 refrigerant circuit

30 compressor

34 first compression mechanism (low pressure side compression mechanism)

35 second compression mechanism (high pressure side compression mechanism)

Best Mode for Carrying out the Invention

[0028] A refrigerating apparatus in accordance with one embodiment composes an air conditioner (1) performing indoor air conditioning. The air conditioner (1) is capable of heating and cooling the interior of a room.

[0029] The air conditioner (1) includes an indoor unit (11) installed indoors and an outdoor unit (12) installed outdoors. The indoor unit (11) and the outdoor unit (12) are connected to each other by means of two communication pipes. Accordingly, a refrigerant circuit (10) is formed across the indoor unit (11) and the outdoor unit (12) in the air conditioner (1). In the refrigerant circuit (10), CO₂ refrigerant is filled so that a two-stage compression/two-stage expansion refrigeration cycle is performed with the CO₂ refrigerant at high pressure utilized as that at its critical pressure.

[0030] In the indoor unit (11), an indoor heat exchanger (13) is provided which is of fin-and-tube type. In the indoor heat exchanger (13), the indoor air blown by an indoor fan is heat-exchanged with the refrigerant.

[0031] The outdoor unit (12) includes a compressor (30), which will be described later, an outdoor heat exchanger (14), and a gas-liquid separator (15).

[0032] The outdoor heat exchanger (14) is of fin-and-tube type. In the outdoor heat exchanger (14), the outdoor air blown by an outdoor fan is heat-exchanged with the refrigerant.

[0033] The gas-liquid separator (15) is composed of a cylindrical hermetic container. An inflow pipe (15a) and a gas injection pipe (15b) are connected to the gas-liquid separator (15) so as to pass through the top of the gas-liquid separator (15). The gas injection pipe (15b) forms a flow path for introducing gas refrigerant at intermediate pressure into the compressor (30). An outflow pipe (15c) is connected to the gas-liquid separator (15) so as to pass through the lower part of the gas-liquid separator (15). In the gas-liquid separator (15), the intermediate-pressure refrigerant in a gas-liquid two-phase state is separated into gas refrigerant and liquid refrigerant.

[0034] The outdoor unit (12) further includes a four-way switching valve (16), a bridge circuit (17), a first expansion valve (18), and a second expansion valve (19).

[0035] The four-way switching valve (16) includes first to fourth ports. In the four-way switching valve (16), the first port is connected to a discharge pipe (41) of the compressor (30), the second port is connected to the outdoor heat exchanger (14), the third port is connected to the indoor heat exchanger (13), and the fourth port is connected to a suction pipe (42) of the compressor (30). The four-way switching valve (16) is exchangeable between a state (the state indicated by solid lines in FIG.

1) in which the first port and the second port communicate with each other while the third port and the fourth port communicate with each other and a state (the state indicated by broken lines in FIG. 1) in which the first port and the third port communicate with each other while the second port and the fourth port communicate with each other.

[0036] The bridge circuit (17) is composed of four pipes in a bridge like combination and four check valves provided at the pipes. The check valves of the bridge circuit (17) allow the refrigerant to flow only in the directions indicated by the arrows in FIG. 1.

[0037] The first expansion valve (18) and the second expansion valve (19) are electronic expansion valves of which opening is adjustable. The first expansion valve (18) is provided in the piping on the inflow side of the gas-liquid separator (15) while the second expansion valve (19) is provided in the piping on the outflow side thereof.

[0038] As shown in FIG. 2, the compressor (30) is composed of a generally-called two-stage compression type compressor that compresses refrigerant in two stages by two compression mechanisms. The compressor (30) includes a cylindrical hermetic casing (31). An electric motor (32), a drive shaft (33), a first compression mechanism (34), and a second compression mechanism (35) are accommodated in the casing (31).

[0039] The electric motor (32) is composed of a stator fixed on the inner peripheral face of the casing (31) and a rotor fixed on the outer peripheral face of the drive shaft (33). The drive shaft (33) is supported by a bearing so as to extend vertically. The drive shaft (33) is rotatable by being driven by the electric motor (32).

[0040] The first compression mechanism (34) is arranged near the bottom of the casing (31) and serves as a low pressure side compression mechanism. On the other hand, the second compression mechanism (35) is arranged near the electric motor (32) and serves as a high pressure side compression mechanism.

[0041] The first compression mechanism (34) and the second compression mechanism (35) are rotary swing type compression mechanisms. Pistons are accommodated in cylindrical cylinder chambers of the compression mechanisms (34, 35). Each piston is connected to the drive shaft (33) so as to be eccentric from the axis of the drive shaft (33). Accordingly, when the drive shaft (33) is rotated, each piston of the compression mechanisms (34, 35) rotates with their centers being eccentric with respect to the drive shaft (33). Further, the pistons of the compression mechanisms (34, 35) are connected to the drive shaft (33) so as to be phase-shifted by 180° from each other. This offsets the centrifugal forces of the pistons in operation, thereby suppressing vibration and variation in torque load.

[0042] The first compression mechanism (34) is connected on the suction side thereof to the suction pipe (42) and is connected on the discharge side thereof to one end of an intermediate communication pipe (43). The

second compression mechanism (35) is connected on the suction side thereof to the other end of the intermediate communication pipe (43) and is connected on the discharge side thereof to the discharge pipe (41).

5 [0043] The intermediate communication pipe (43) forms a flow path for introducing the refrigerant after being compressed in the first compression mechanism (34) into the suction side of the second compression mechanism (35). The outflow end of the gas injection pipe (15b) is connected to a U-shape curved part of the intermediate communication pipe (43).

10 [0044] In the air conditioner (1) of the present embodiment, the ratio (volume ratio $V2/V1$) of the displacement volume $V2$ of the second compression mechanism (35) to that $V1$ of the first compression mechanism (34) are set in the range between 0.8 and 1.3, both exclusive. This increases the COP (coefficient of performance) of the air conditioner (1). The relationship between the volume ratio $V2/V1$ and the COP will be described later in detail.

- Driving operations -

25 [0045] Driving operations of the air conditioner (1) in accordance with the present embodiment will be described. The air conditioner (1) is capable of performing the following heating and cooling operations.

<Heating operation>

30 [0046] In the heating operation, the four-way switching valve (16) is set as shown in FIG. 2. Each opening of the first expansion valve (18) and the second expansion valve (19) is adjusted appropriately.

35 [0047] The refrigerant compressed up to its critical pressure is discharged from the compressor (30). The refrigerant passes through the four-way switching valve (16) and then flows into the indoor heat exchanger (13). In the indoor heat exchanger (13), the refrigerant releases heat to the indoor air. This means indoor heating. The refrigerant flowing out from the indoor heat exchanger (13) passes through the first expansion valve (18) to be reduced in pressure up to intermediate pressure and flows then into the gas-liquid separator (15).

40 [0048] In the gas-liquid separator (15), the intermediate-pressure refrigerant in the gas-liquid two-phase state is retained. This refrigerant is separated into the gas refrigerant and the liquid refrigerant in the gas-liquid separator (15). The gas refrigerant retained in the upper part of the gas-liquid separator (15) flows into the gas injection pipe (15b). On the other hand, the liquid refrigerant retained in the lower part of the gas-liquid separator (15) passes through the second expansion valve (19) to be reduced in pressure up to low pressure and flows then into the outdoor heat exchanger (14). In the outdoor heat exchanger (14), the refrigerant absorbs heat from the outdoor air to be evaporated. The refrigerant flowing out from the outdoor heat exchanger (14) is sucked into the

compressor (30).

[0049] In the compressor (30), the refrigerant is first sucked into the first compression mechanism (34) through the suction pipe (42). The refrigerant is compressed up to intermediate pressure in the first compression mechanism (34). The refrigerant discharged from the first compression mechanism (34) flows into the intermediate communication pipe (43). This discharged refrigerant is mixed with the gas refrigerant flowing out from the gas injection pipe (15b). As a result, the temperature of the refrigerant discharged from the first compression mechanism (34) lowers. The refrigerant flowing out from the intermediate communication pipe (43) is sucked into the second compression mechanism (35). In the second compression mechanism (35), the refrigerant is compressed up to its critical pressure.

- Cooling operation -

[0050] In the cooling operation, the four-way switching valve (16) is set as shown in FIG. 3. Each opening of the first expansion valve (18) and the second expansion valve (19) is adjusted appropriately.

[0051] The refrigerant compressed up to its critical pressure is discharged from the compressor (30). The refrigerant passes through the four-way switching valve (16) and flows then into the outdoor heat exchanger (14). In the outdoor heat exchanger (14), the refrigerant releases heat to the outdoor air. The refrigerant flowing out from the outdoor heat exchanger (14) passes through the first expansion valve (18) to be reduced in pressure up to intermediate pressure and flows then into the gas-liquid separator (15).

[0052] In the gas-liquid separator (15), the intermediate-pressure refrigerant in the gas-liquid two-phase state is retained. This refrigerant is separated into the gas refrigerant and the liquid refrigerant in the gas-liquid separator (15). The gas refrigerant retained in the upper part of the gas-liquid separator (15) flows into the gas injection pipe (15b). On the other hand, the liquid refrigerant retained in the lower part of the gas-liquid separator (15) passes through the second expansion valve (19) to be reduced in pressure up to low pressure and flows then into the indoor heat exchanger (13). In the indoor heat exchanger (13), the refrigerant absorbs heat from the indoor air to be evaporated. This means indoor cooling. The refrigerant flowing out from the indoor heat exchanger (13) is sucked into the compressor (30).

[0053] In the compressor (30), the refrigerant is first sucked into the first compression mechanism (34) through the suction pipe (42). The refrigerant is compressed up to intermediate pressure in the first compression mechanism (34). The refrigerant discharged from the first compression mechanism (34) flows into the intermediate communication pipe (43). This discharged refrigerant is mixed with the gas refrigerant flowing out from the gas injection pipe (15b). As a result, the temperature of the refrigerant discharged from the first compression

mechanism (34) lowers. The refrigerant flowing out from the intermediate communication pipe (43) is sucked into the second compression mechanism (35). In the second compression mechanism (35), the refrigerant is compressed up to its critical pressure.

- Relationship between volume ratio between two compression mechanisms and COP -

[0054] As described above, in the heating operation and the cooling operation of the air conditioner (1) of the present embodiment, the generally-called intermediate pressure gas injection is performed by mixing the gas refrigerant separated in the gas-liquid separator (15) with the intermediate-pressure refrigerant in the compressor (30). As a result, in this air conditioner (1), the temperature of the refrigerant discharged from the first compression mechanism (34) is lowered and the power required for driving the compressor (30) is reduced, thereby increasing the COP.

[0055] In the refrigerant circuit (10) of the air conditioner (1), a generally-called supercritical cycle is performed by compressing the high-pressure refrigerant up to its critical pressure. Therefore, if the intermediate-pressure refrigerant in the gas-liquid separator (15) reaches its critical pressure, it becomes difficult to separate the refrigerant in the gas-liquid separator (15) into the gas refrigerant and the liquid refrigerant, thereby inhibiting performance of the intermediate pressure gas injection. To tackle this problem, in the present invention, the volume ratio ($V2/V1$) of the volume $V2$ of the second compression mechanism (35) to that $V1$ of the first compression mechanism (34) is set in the optimum range to allow the pressure of the intermediate-pressure refrigerant in the gas-liquid separator (15) to be lower than its critical pressure, thereby enabling desired intermediate pressure gas injection.

[0056] FIG. 4 shows the result obtained by examining the above relationship between the volume ratio ($V2/V1$) and the COP. In FIG. 4, the COPs in the heating operation and the cooling operation are obtained in air conditioners having volume ratios ($V2/V1$) different from each other. Specifically, in FIG. 4, each COP of the air conditioners is obtained in the heating operation under a temperature condition in the outdoor temperature range (from -10°C to 15°C) in general winter season and in the cooling operation under a temperature condition in the outdoor temperature range (from 25°C to 35°C) in general summer season. The "COP ratio" herein means a relative evaluation of each COP of the air conditioners with various volume ratios with reference to, as a standard, the lowest COP of an air condition with a volume ratio of 0.65 (for example, the COP in the heating operation at an outdoor temperature of 15°C and the COP in the cooling operation at an outdoor temperature of 25°C).

[0057] As shown in FIG. 4, the air conditioners with volume ratios of 0.8 or smaller have low COPs in the heating operation and the cooling operation. This is be-

cause: with a volume ratio of 0.8 or smaller, the displacement volume of the second compression mechanism (35) is too small relative to that of the first compression mechanism (34), so that the refrigerant in the gas-liquid separator (15) exceeds its critical pressure to inhibit separation of the gas refrigerant from the refrigerant in the gas-liquid separator (15), thereby inhibiting desired intermediate pressure gas injection. In contrast, with a volume ratio greater than 0.8, the refrigerant in the gas-liquid separator (15) can be allowed to reach its subcritical pressure to leads to separation of the gas refrigerant from the refrigerant in the gas-liquid separator (15). Thus, the air conditioner with a volume ratio greater than 0.8 can perform desired intermediate pressure gas injection, thereby attaining a high COP.

[0058] On the other hand, the air conditioner with a volume ratio of 1.3 has low COPs in the heating operation and in the cooling operation under a low outdoor temperature condition. This is because: with a volume ratio of 1.3 or greater, the displacement volume of the second compression mechanism (35) is too great relative to that of the first compression mechanism (34), so that an insufficient amount of the refrigerant sucked in the second compression mechanism (35) is secured. In other words, with a volume ratio of 1.3 or greater, the refrigerant is compressed in two stages inefficiently to increase the power required for driving the compressor (30) with a result of lowering of the COP. In reverse, the air conditioner with a volume ratio smaller than 1.3 can perform relatively efficient two-stage compression of the refrigerant to attain a high COP.

[0059] In addition, as shown in FIG. 4, each COP in the cooling operation and in the heating operation is high when the volume ratio is not within the range between 0.9 and 1.1, both inclusive. Accordingly, the volume ratio (V_2/V_1) of the volume V_2 of the second compression mechanism (35) to that V_1 of the first compression mechanism (34) is preferably within the range between 0.9 and 1.1, both inclusive. Particularly, when the volume ratio is set at 1.0, a high COP can be attained in each of the cooling operation and the heating operation.

- Effects of Embodiment -

[0060] In the above embodiment, the volume ratio of the second compression mechanism (35) to the first compression mechanism (34) is set within the range between 0.8 and 1.3, both exclusive. When the volume ratio is set greater than 0.8, the pressure of the refrigerant in the gas-liquid separator (15) is allowed to be smaller than its critical pressure. This attains desired intermediate pressure gas injection in the refrigerant circuit (10) to increase the COP of the air conditioner (1) in the present embodiment. Further, when the volume ratio is set smaller than 1.3, the refrigerant can be compressed in two stages with no lowering of the compression efficiency invited, which is accompanied by an insufficient amount of the refrigerant sucked in the second compression mechanism (35).

Hence, according to the above embodiment, the COP of the air conditioner (1) can be increased further.

[0061] Particularly, when the volume ratio of the second compression mechanism (35) to the first compression mechanism (34) is set within the range between 0.9 and 1.1, both inclusive, a high COP can be obtained as shown in FIG. 4.

[0062] Further, when the volumes of the first compression mechanism (34) and the second compression mechanism (35) are set equal to each other (volume ratio is 1.0), a high COP can be obtained in each of the cooling operation and the heating operation. In addition, when the volumes of the first compression mechanism (34) and the second compression mechanism (35) are set equal to each other, the compression mechanisms can be structured according to the same specification in their compression mechanism. Hence, the compressor (30) can be manufactured comparatively easily at low cost.

<Other Embodiments>

[0063] The above embodiment may have any of the following structure.

[0064] In the above embodiment, the discharge side of the low pressure side compression mechanism (34) and the suction side of the high pressure side compression mechanism (35) are connected by means of the intermediate communication pipe (43), and the outflow end of the gas injection pipe (15b) is connected to the intermediate communication pipe (43). However; the intermediate-pressure gas refrigerant may be introduced into the casing (31) in the case where the compressor (30) is a generally-called intermediate pressure dome type compressor by filling the casing (31) of the compressor (30) with the refrigerant discharged from, for example, the low pressure side compression mechanism (34).

[0065] Further, the low pressure side compression mechanism (34) and the high pressure side compression mechanism (35) are composed of swing type compression mechanisms in the above embodiment but may be rotary piston type compression mechanisms or compression mechanisms each composed of an anchor tooth and a movable tooth (of scroll type, for example).

[0066] It should be noted that the above embodiments are mere essentially preferable examples and is not intended to limit the present invention, applicable objects, and usable range.

Industrial Applicability

[0067] As described above, the present invention is useful in refrigerating apparatuses including a refrigerant circuit including a gas-liquid separator for performing two-stage compression/two-state expansion refrigeration cycle utilizing CO₂ refrigerant at high pressure as that at its critical pressure.

Claims

1. A refrigerating apparatus comprising a refrigerant circuit for performing a two-stage compression/two-stage expansion refrigeration cycle in which CO₂ refrigerant at high pressure is utilized as that at its critical pressure, the refrigerant circuit including: a compressor including a low pressure side compression mechanism and a high pressure side compression mechanism connected to each other by means of a drive shaft; and a gas-liquid separator for separating refrigerant at intermediate pressure into gas refrigerant and liquid refrigerant, wherein a volume ratio of a displacement volume of the high pressure side compression mechanism to that of the low pressure side compression mechanism falls in a range between 0.8 and 1.3, both exclusive. 5 10 15
2. The refrigerating apparatus of Claim 1, wherein the volume ratio falls in a range between 0.9 and 1.1, both inclusive. 20
3. The refrigerating apparatus of Claim 2, wherein the volume ratio is 1.0. 25
4. The refrigerating apparatus of any one of Claims 1 to 3, wherein the low pressure side compression mechanism and the high pressure side compression mechanism are rotary compression mechanisms. 30

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FIG. 1

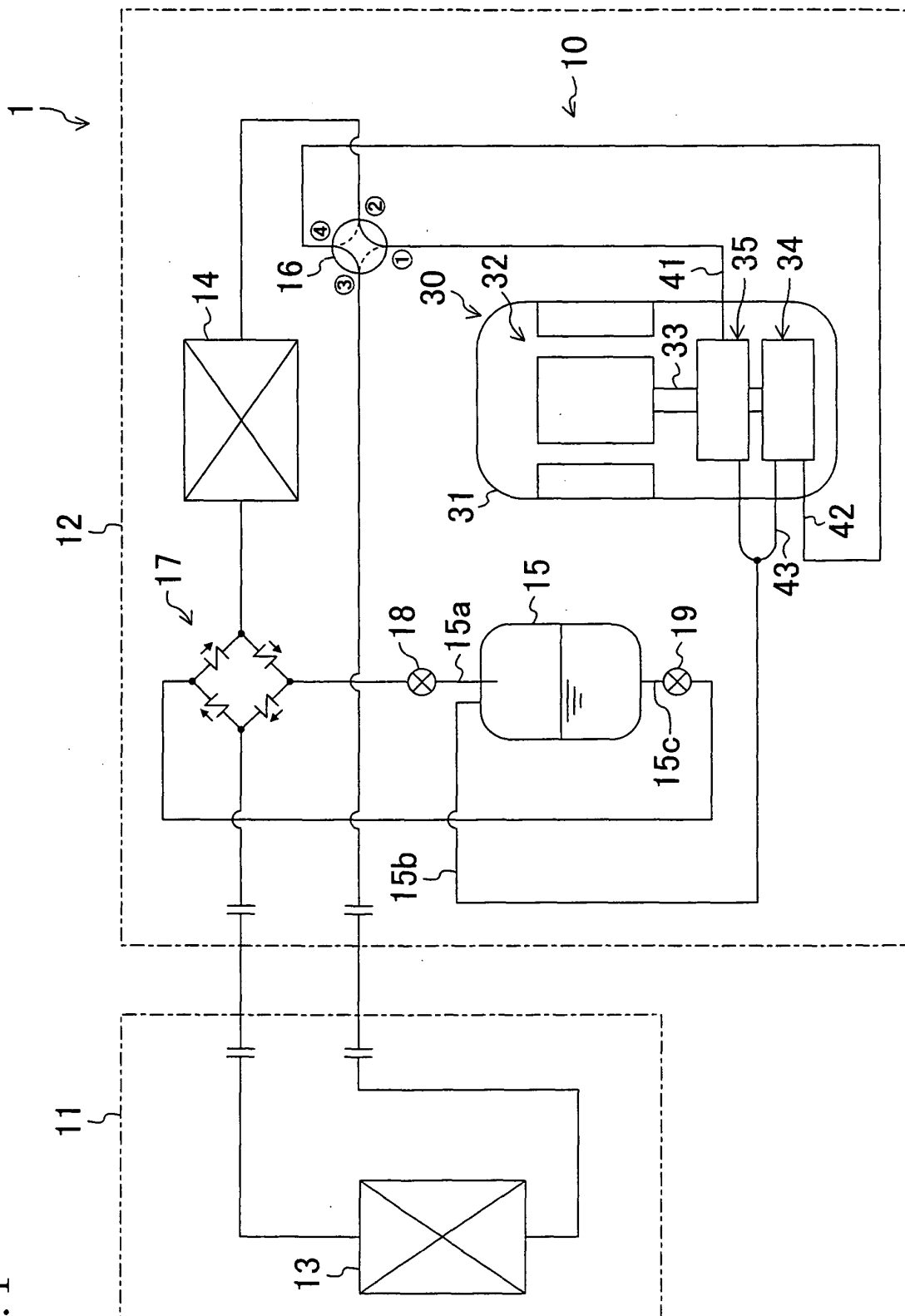


FIG. 2

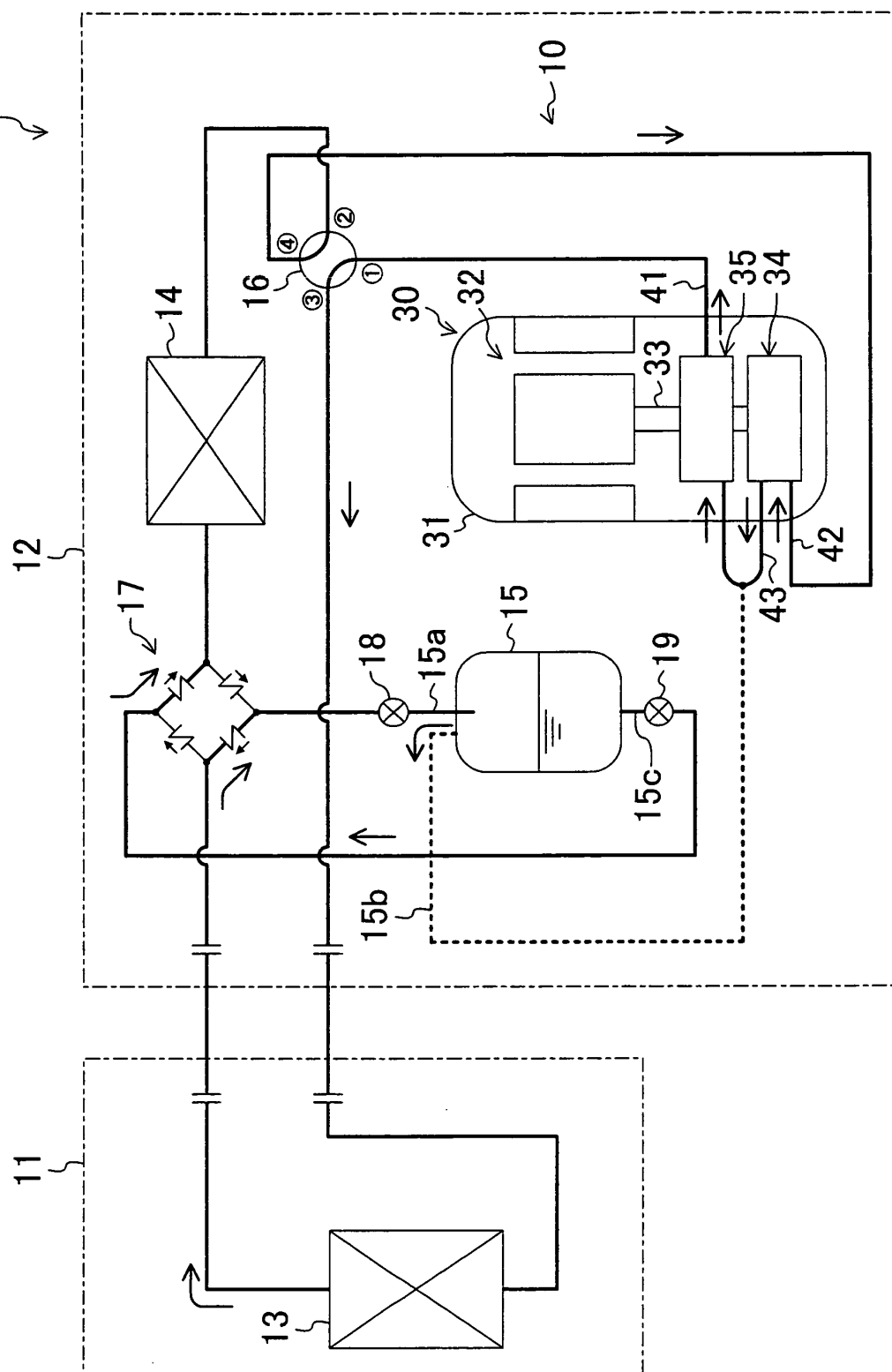


FIG. 3

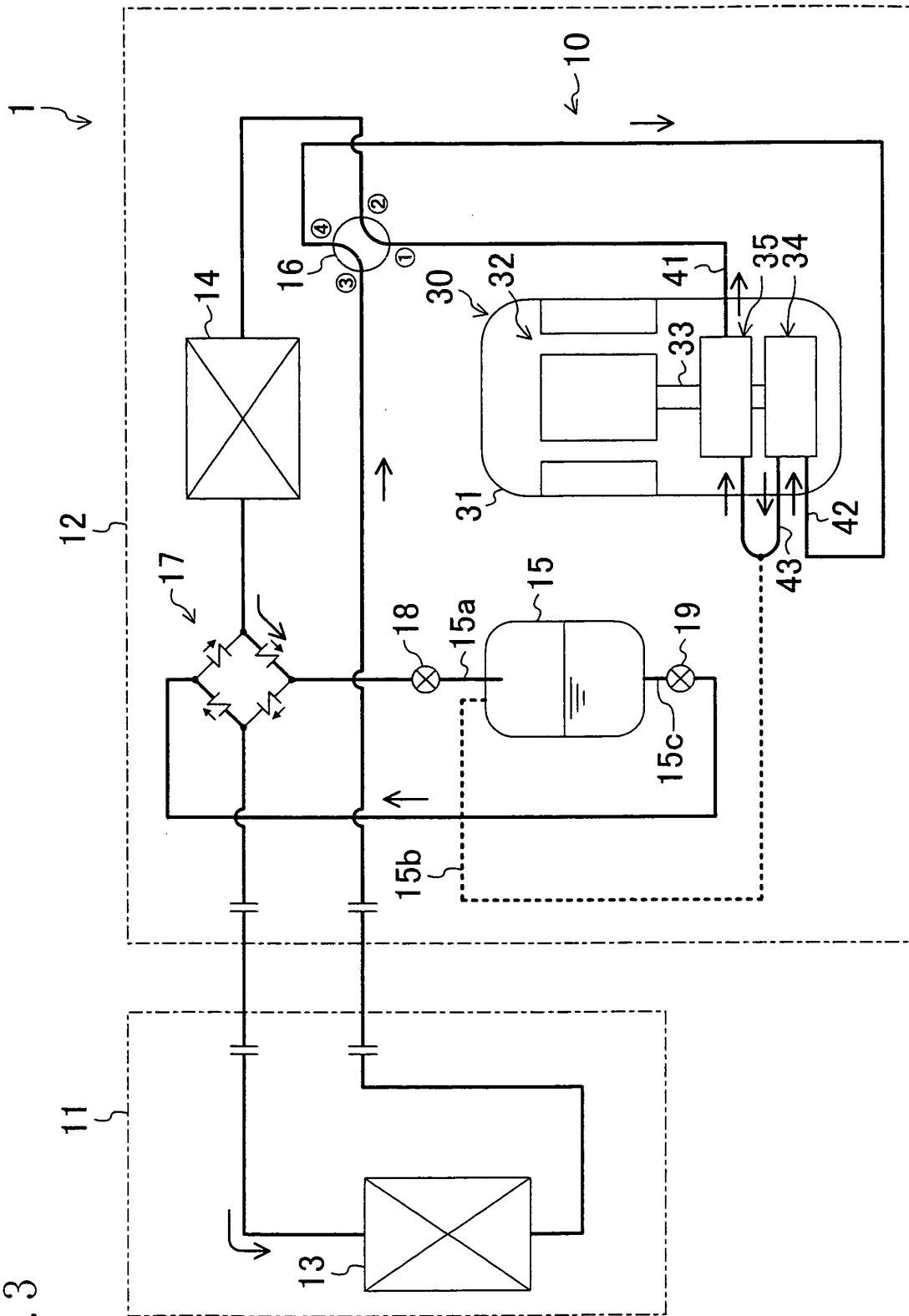
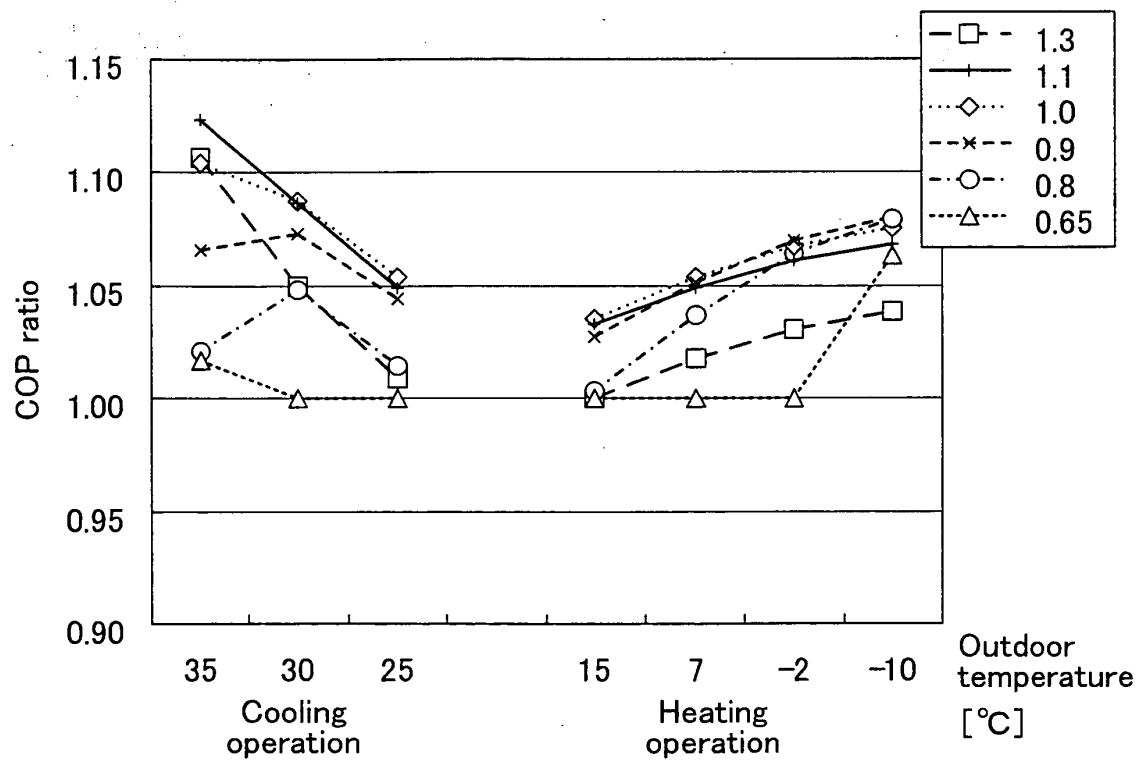


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/053255

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/10(2006.01) i, F25B1/00(2006.01) i, F25B1/04(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)

F25B1/10, F25B1/00, F25B1/04

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 1996-2007

Kokai Jitsuyo Shinan Koho 1971-2007 Toroku Jitsuyo Shinan Koho 1994-2007

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	JP 11-304269 A (Nippon Soken, Inc.), 05 November, 1999 (05.11.99), Par. Nos. [0020] to [0025], [0043], [0044]; Fig. 1 (Family: none)	1-4
P,X	JP 2006-242557 A (Thermal Analysis Partners, L.L.C.), 14 September, 2006 (14.09.06), Par. Nos. [0029], [0044]; Fig. 1 & EP 1703239 A & US 2006-191288 A & NO 20060909 A	1-4
A	JP 11-241693 A (Sanyo Electric Co., Ltd.), 07 September, 1999 (07.09.99), Full text; Figs. 1 to 16 (Family: none)	1-4

☒ 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	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
15 May, 2007 (15.05.07)Date of mailing of the international search report
29 May, 2007 (29.05.07)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/053255

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2001-74325 A (Matsushita Refrigeration Co.), 23 March, 2001 (23.03.01), Par. No. [0053] (Family: none)	1-4
A	JP 2003-83247 A (Toshiba Carrier Corp.), 19 March, 2003 (19.03.03), Par. No. [0043] (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 2001241797 A [0008]