



(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
19.08.2009 Bulletin 2009/34

(21) Application number: **07850281.2**

(22) Date of filing: **07.12.2007**

(51) Int Cl.:
F01C 21/18 (2006.01) **F01C 1/02** (2006.01)
F01C 1/356 (2006.01) **F01C 11/00** (2006.01)
F01C 13/04 (2006.01) **F01C 20/18** (2006.01)
F01C 20/24 (2006.01) **F25B 1/00** (2006.01)
F25B 11/02 (2006.01)

(86) International application number:
PCT/JP2007/073703

(87) International publication number:
WO 2008/072575 (19.06.2008 Gazette 2008/25)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR

(30) Priority: **08.12.2006 JP 2006331664**
06.12.2007 JP 2007316259

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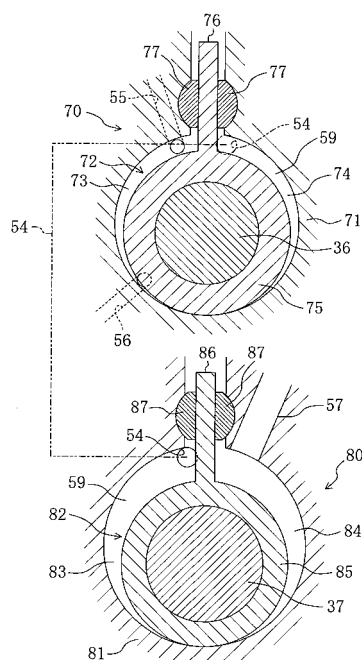
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(54) **FREEZING APPARATUS, AND EXPANDER**

(57) A refrigerating apparatus is obtained which can recover the energy of high pressure refrigerant in an expansion mechanism as power to maximum, and can change the suction amount of the refrigerant in the expansion mechanism.

The expansion mechanism (50) includes two rotary mechanism sections (70, 80) having displacement volumes different from each other. The rotary mechanism sections are connected in series to each other. Two suction ports (55, 56) are formed in a cylinder of a rotary mechanism section having a smaller displacement volume. Inflow pipes (24, 27) connected to the suction ports (55, 56) include a pre-throttle valve (60) and an on-off valve (61), respectively. A bypass valve (66) is provided in a bypass pipe (65) bypassing the expansion mechanism (50). Control on the valves (60, 61, 66) achieves balance between the refrigerant circulation amount in the expansion mechanism (50) and the refrigeration circulation amount in a compression mechanism (40).

FIG. 4



Description**TECHNICAL FIELD**

[0001] The present disclosure relates to refrigerating apparatuses including an expansion mechanism, and particularly relates to a displacement expansion mechanism generating power by fluid expansion.

BACKGROUND ART

[0002] Conventionally, refrigerant circuits performing a refrigeration cycle have been known which include a compression mechanism and an expansion mechanism recovering power from refrigerant, as disclosed in Patent Documents 1 and 2. The power recovered from high pressure refrigerant in the expansion mechanism is transmitted to the compression mechanism connected through a drive shaft to be utilized for driving the compression mechanism.

[0003] Because the refrigerant circuit is a closed circuit, the circulation amount of the refrigerant passing through the compression mechanism per unit time (corresponding to a mass flow rate, the same is applied below) must agree with the circulation amount of the refrigerant passing through the expansion mechanism. However, in the case where the expansion mechanism is designed according to a given layout specification (for example, rated heating), driving under a condition deviated from the design specification may cause discrepancy between the circulation amount in the compression mechanism and that in the expansion mechanism. For example, where the refrigerating apparatus is designed so that the circulation amount in the compression mechanism agrees with that in the expansion mechanism in the rated heating operation, since the optimum suction volume of the expansion mechanism is larger in the rated cooling operation, in which the suction pressure of the compression mechanism becomes high, than in the rated heating operation, the refrigerant may be short to cause excessive expansion.

[0004] In view of this, in Patent Documents 1 and 2, the high pressure refrigerant is injected in the expansion stroke of the expansion mechanism, or a passage bypassing the expansion mechanism is provided to adjust the amount of the refrigerant bypassing by a control valve, thereby balancing the flow rate of the refrigerant between the compression mechanism and the expansion mechanism of the refrigerant circuit.

Patent Document 1: Japanese Unexamined Patent Application Publication 2004-150748

Patent Document 2: Japanese Unexamined Patent Application Publication 2001-116371

SUMMARY**PROBLEMS THAT THE INVENTION IS TO SOLVE**

[0005] However, though injection of the high pressure refrigerant to the expansion mechanism in the expansion stroke or refrigerant bypassing the expansion mechanism can balance the refrigerant circulation amount between the compression mechanism and the expansion mechanism, only part of the energy of the high pressure refrigerant, which should be recovered primarily to maximum as power, can be recovered by the expansion mechanism. Therefore, it cannot be said that they are preferable structures in view efficiency.

[0006] The present invention has been made in view of the foregoing, and its objective is to obtain a refrigerating apparatus which can recover the energy of the high pressure refrigerant in the expansion mechanism as power to maximum, and which can change the suction amount of the refrigerant in the expansion mechanism

MEANS FOR SOLVING THE PROBLEMS.

[0007] To attain the above objective, a refrigerating apparatus (1) in accordance with the present invention includes, in an expansion mechanism (50, 100, 200), a main suction hole (55, 103, 201) first connected to a fluid chamber (72, 82, 230) in the suction stroke, and an auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) connected thereto after connection of the main suction hole (55, 103, 201).

[0008] Specifically, a first aspect of the present invention is directed to a refrigerating apparatus including an expansion mechanism (50, 100, 200) which includes a first member (71, 81, 102, 112, 210) and a second member (75, 85, 116, 124, 220), which are in eccentric and relative movement, and generates power by expansion of fluid in a fluid chamber (72, 82, 230) formed between the members.

[0009] In the refrigerating apparatus, a main suction hole (55, 103, 201) connecting the fluid chamber (72, 82, 230) to a suction passage (24) first in a suction stroke, and an auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) connecting the fluid chambers (72, 82, 230) to a suction passage (27) after connection of the main suction hole (55, 103, 201) are formed in the expansion mechanism (50, 100, 200).

[0010] With the above configuration, the fluid can be introduced into the fluid chamber (72, 82, 230) sequentially from the plurality of suction holes (55, 56, 103, 104, 113, 114, 201, 203, 204, 205) in the suction stroke of the expansion mechanism (50, 100, 200), thereby adjusting the fluid circulation amount in the fluid chamber (72, 82, 230).

[0011] Accordingly, even when the driving condition is changed, the circulation amount can be balanced between the expansion mechanism (50, 100, 200) and a compression mechanism (400), and all the fluid can be

introduced into the fluid chamber (72, 82, 230) in the suction stroke. Hence, the expansion mechanism (50, 100, 200) can recover the power efficiently.

[0012] In the above configuration, in the expansion mechanism (50, 100, 200), the fluid chamber (72, 82, 230) is defined so that at least a suction stroke and a discharge stroke are performed independently (a second aspect of the present invention). For example, in the case where the suction stroke and the discharge stroke are performed independently, as in a multistage type or scroll type expander, the high pressure fluid introduced in the fluid chamber in the suction stroke is prevented from flowing outside directly without being expanded in the expansion mechanism (50, 100, 200). Accordingly, the above configuration can achieve sufficient fluid expansion in the expansion mechanism (50, 100, 200).

[0013] It is preferable that the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) is formed to open at a bottom of the fluid chamber (72, 230) (a third aspect of the present invention). Formation of the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) through the bottom of the fluid chamber (72, 230) allows the refrigerator oil in the expansion mechanism (50, 100, 200) to stay in the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) when the fluid is not introduced from the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205). This can prevent the suction passage (27) from being a dead volume passage in which the fluid in the fluid chamber (72, 230) is retained, thereby achieving efficient fluid expansion in the fluid chamber (72, 230).

[0014] Further, it is preferable that an on-off valve (61) is provided in the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205), and a check valve (95) allowing flow from the on-off valve (61) to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) is provided downstream of the on-off valve (61) (a fourth aspect of the present invention).

[0015] The check valve (95) can ensure prevention of the fluid in the fluid chamber (72, 82, 230) from flowing into the suction passage (27). Hence, reduction in ineffective volume of the expansion mechanism (50, 100, 200) can be further ensured, and the fluid can be expanded further efficiently in the expansion mechanism (50, 100, 200).

[0016] It is preferable to provide a bypass circuit (65) bypassing the expansion mechanism (50, 100, 200); and a bypass flow rate adjusting valve (66) provided in the bypass circuit (65) (a fifth aspect of the present invention). The bypass circuit (65) and the bypass flow rate adjusting valve (66) enables fine adjustment of the fluid circulation amount in the expansion mechanism (50, 100, 200). Further, even when the fluid circulation amount is greatly increased when compared with a normal driving operation, such as immediately after startup, in a defrost operation, and the like, the increased amount of the fluid can be absorbed to suppress an increase in pressure on the suction side of the expansion mechanism (50, 100,

200).

[0017] The configuration including the above bypass flow rate adjusting valve (65) further includes a bypass flow rate control means (94) configured to control the bypass flow rate adjusting valve (66) on the basis of a pressure of the fluid introduced in the expansion mechanism (50, 100, 200) (a sixth aspect of the present invention). This can adjust the amount of the refrigerant bypassing the expansion mechanism (50, 100, 200) so that the pressure introduced to the expansion mechanism (50, 100, 200) is a target value.

[0018] It is preferable to provide a flow rate adjusting valve (60) in the suction passage (24) connected to the main suction hole (55, 103, 201) (a seventh aspect of the present invention). This enables the flow rate adjusting valve (60) to adjust the circulation amount of the fluid introduced to the fluid chamber (72, 82, 230) from the main suction hole (55, 103, 201), thereby allowing the optimum amount of the fluid to flow to the expansion mechanism (50, 100, 200) according to the fluid circulation amount in the compression mechanism (40).

[0019] Particularly, the flow rate adjusting valve (60) is preferably disposed downstream of a point branching apart from the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) (an eighth aspect of the present invention). This can adjust only the circulation amount of the fluid introduced from the main suction hole (55, 103, 201) without changing the circulation amount of the fluid introduced from the auxiliary suction hole.

[0020] The apparatus further includes flow rate control means (92) configured to control the flow rate adjusting valve (60) on the basis of a pressure of the fluid introduced in the expansion mechanism (50, 100, 200) (a ninth aspect of the present invention). Accordingly, the fluid circulation amount in the expansion mechanism (50, 100, 200) can be adjusted so that the pressure of the fluid introduced to the expansion mechanism (50, 100, 200) becomes a target value.

[0021] The apparatus includes on-off valve control means (93) configured to control an on-off valve (61) provided in the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) on the basis of a pressure of the fluid introduced in the expansion mechanism (50, 100, 200) (a tenth aspect of the present invention). Control on the on-off valve (61) by the on-off valve control means (93) can result in control of the flow rate of the fluid introduced to the fluid chamber (72, 82, 230). In other words, control on the on-off valve (61) based on the pressure of the fluid introduced to the expansion mechanism (50, 100, 200) can result in control of the flow rate so that the expansion mechanism (50, 100, 200) is at the optimum pressure, that is, at the optimum circulation amount, thereby achieving efficient fluid expansion in the expansion mechanism (50, 100, 200).

[0022] Specifically, a plurality of auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) are provided in the expander, and on-off valves (61) are provided in the suc-

tion passages (27) connected to the auxiliary holes, and when the pressure is larger than a target value, the on-off valve control means (93) opens the on-off valves (61) sequentially so that the fluid chamber (72, 82, 230) is connected sequentially to the suction passages (27) through the auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) (an eleventh aspect of the present invention).

[0023] When the pressure of the fluid introduced in the expansion mechanism (50, 10, 200) is larger than the target value, that is, when the circulation amount of the fluid to the expansion mechanism (50, 100, 200) should be increased, sequential opening of the on-off valves (61) can increase stepwise the circulation amount of the fluid introduced to the fluid chamber (72, 82, 230). Accordingly, even when the circulation amount necessary in the fluid chamber (72, 82, 230) is changed greatly, opening of the on-off valves (61) enables quick introduction of the fluid to the fluid chamber (72, 82, 230).

[0024] In reverse, when the pressure is smaller than the target value, the on-off valve control means (93) controls the on-off valves (61) to sequentially close the auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) in reverse order of connection from one connected to the fluid chamber (72, 82, 230) last (a twelfth aspect of the present invention).

[0025] When the pressure of the fluid introduced in the expansion mechanism (50, 100, 200) is smaller than the target value, that is, when the circulation amount in the expansion mechanism (50, 100, 200) is large and should be reduced, sequential closing of the on-off valves (61) can reduce stepwise the circulation amount of the fluid introduced to the fluid chamber (72, 82, 230). Accordingly, even when the circulation amount necessary in the fluid chamber (72, 82, 230) is changed greatly, closing of the on-off valves (61) can quickly reduce the flow rate of the fluid to the fluid chamber (72, 82, 230).

[0026] In the configuration including bypass flow rate control means (94) for controlling a bypass flow rate adjusting valve (66) provided in the bypass circuit (65) bypassing the expansion mechanism (50, 100, 200), the bypass flow rate control means (94) controls the bypass flow rate adjusting valve (66) so that the pressure value is the target value, and the on-off valve control means (93) opens/closes the on-off valves (61) when the bypass flow rate adjusting valve (66) reaches a predetermined opening (a thirteenth aspect of the present invention). Herein, the term, "predetermined opening" means a sufficiently large opening that cannot be increased further when the on-off valve (61) is opened, and means an opening of almost zero when the on-off valve (61) is closed.

[0027] By doing so, the bypass flow rate adjusting valve (66) in the bypass circuit (65) can adjust finely the circulation amount of the fluid introduced to the fluid chamber (72, 82, 230) of the expansion mechanism (50, 100, 200). Further, when the bypass flow rate adjusting valve (66) cannot adjust it further more, the opening/closing control on the on-off valves (61) can increase/de-

crease the circulation amount in the fluid chamber (72, 82, 230) quickly and reliably. Hence, the flow rate can be adjusted quickly and reliably so that expansion mechanism (50, 100, 200) is at the optimum circulation amount.

[0028] Furthermore, in the configuration including flow rate control means (92) for controlling a flow rate adjusting valve (60) provided in the suction passage (24) connected to the main suction hole (55, 103, 201), the flow rate control means (92) controls the flow rate adjusting valve (60) to adjust a flow rate in the expansion mechanism (50, 100, 200) when the pressure is smaller than the target value even when the bypass flow rate adjusting valve (66) and the on-off valve (61) are closed (a fourteenth aspect of the present invention).

[0029] In order to reduce the circulation amount of the fluid in the expansion mechanism (50, 100, 200), the bypass flow rate adjusting valve (66) and the on-off valves (61) are closed to reduce the circulation amount of the fluid introduced from the auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) for introducing the fluid into the fluid chamber (72, 82, 230) only from the main suction hole (55, 103, 201). When the fluid circulation amount is still too large, the flow rate adjusting valve (60) adjusts the flow rate. This ensures quick reduction in the amount of the fluid introduced to the fluid chamber (72, 82, 230).

[0030] Moreover, it is preferable that the expansion mechanism (50, 100) includes a plurality of rotary mechanism sections (70, 80, 101, 111, 121) connected to each other in series in an increasing order of displacement volume, and the main suction hole (55, 103) and the auxiliary suction hole (56, 104, 113, 114) are formed in a rotary mechanism section (70, 101, 111) precedent to a last rotary mechanism section (80, 121) (a fifteenth aspect of the present invention). In the case where the expansion mechanism (50, 100) is of multistage rotary as above, the fluid at a high pressure is prevented from blow-through from the suction side to the discharge side, thereby achieving efficient fluid expansion in the expansion mechanism (50, 100).

[0031] Particularly, it is preferable that the expansion mechanism (50) includes two rotary mechanism sections (70, 80) connected to each other in series, and the main suction hole (55) and the auxiliary suction hole (56) are formed in a precedent rotary mechanism section (70) having a smaller displacement volume (a sixteenth aspect of the present invention).

[0032] The above two-stage rotary expansion mechanism, which has a simple configuration, can ensure prevention of blow-through of the fluid, thereby resulting in reduction in manufacturing cost.

[0033] In the configuration in which the plurality of rotary mechanism sections (70, 80, 101, 111, 121) are connected in series to each other, the auxiliary suction hole (56, 104, 113, 114) is formed at an angle point obtained by adding a predetermined compensation value to an angle point geometrically obtained based on a desired displacement volume (a seventeenth aspect of the present invention).

[0034] When the angle point where the auxiliary suction hole (56, 104, 113, 114) is set large so as to increase the inflow rate with a decrease in inflow rate taken into consideration which is caused by pressure loss, which is caused when the refrigerant flows into the fluid chamber (72, 230) from the auxiliary suction hole (56, 104, 113, 114), a necessary amount of the fluid can be allowed to flow into the fluid chamber (72, 230). Hence, the necessary amount of refrigerant flowing to the expansion mechanism (50, 100) can be secured.

[0035] Particularly, it is preferable in the above configuration that the desired displacement volume is a displacement volume necessary in a cooling operation (an eighteenth aspect of the present invention).

[0036] Hence, even in the cooling operation where the pressure on the low pressures side is higher than that in the heating operation to necessitate a larger amount of the refrigerant in the expansion mechanism (50, 100), the necessary amount of the refrigerant can be allowed to flow to the fluid chamber (72, 230) with the pressure loss, which is caused when the refrigerant flows into the fluid chamber (72, 230), taken into consideration. Accordingly, excessive expansion, which may be caused by shortage of the refrigerant in the expansion mechanism (50, 100) in the cooling operation, can be prevented.

[0037] Furthermore, the expansion mechanism (200) includes a scroll mechanism including a pair of scroll members (210, 220) including end plates and scroll wraps standing on the end plates, the wraps (211, 221) of the scroll members (210, 220) being in engagement with each other to form at least a pair of fluid chambers (231, 232), and the main suction hole (201) and the auxiliary suction hole (203, 204, 205) are formed at points connected to the fluid chambers (231, 232) in a suction stroke of the scroll mechanism (a nineteenth aspect of the present invention).

[0038] With the above scroll expansion mechanism, the fluid at a high pressure can be prevented from blow-through without necessitating multi stages as in the rotary type one.

[0039] In the above configuration, preferably, refrigerant of CO₂ is used as the fluid for performing a supercritical refrigeration cycle (a twentieth aspect of the present invention). This can obtain a refrigerant circuit suitable for environment.

[0040] A twenty-first aspect of the present invention is directed to an expander including an expansion mechanism (50, 100, 200) which includes a first member (71, 81, 102, 112, 210) and a second member (75, 85, 116, 124, 220), which are in eccentric and relative movement, and generates power by expansion of fluid in a fluid chamber (72, 82, 230) formed between the members.

[0041] In the expansion mechanism (50, 100, 200) of the expander, a main suction hole (55, 103, 201) connecting the fluid chamber (72, 82, 230) to a suction passage (24) first in a suction stroke, and an auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) connecting the fluid chamber (72, 82, 230) to a suction passage (27)

after connection of the main suction hole (55, 103, 201) are formed. Hence, an expander that can exhibit the same operation as in the first aspect can be obtained.

5 ADVANTAGES OF THE INVENTION

[0042] In the refrigerating apparatus in accordance with the present invention, the main suction hole (55, 103, 201) connected first to the fluid chamber (72, 82, 230) in the suction stroke, and the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) then connected thereto are formed in the expansion mechanism (50, 100, 200). This can control the flow rate of the fluid to the fluid chamber (72, 82, 230), and the fluid in the expansion mechanism (50, 100, 200) can be at the optimum circulation amount even when the driving condition is changed greatly. Hence, the expansion mechanism (50, 100, 200) can efficiently expand the fluid to efficiently recover the power.

[0043] In the second aspect of the present invention, at least the suction stroke and the discharge stroke of the expansion mechanism (50, 100, 200) are independent, and therefore, the introduced high pressure fluid can be prevented from blow-through, and fluid expansion in the expansion mechanism (50, 100, 200) can be ensured.

[0044] In the third aspect of the present invention, the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) is formed to open at the lower part of the fluid chamber (72, 82, 230). When the fluid is not introduced from the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205), the refrigerator oil tends to stay inside the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) to cause the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) to be a dead volume hole for the fluid in the fluid chamber (72, 82, 230). However, this configuration can ensure prevention of this phenomenon. Hence, the expansion mechanism (50, 100, 200) can expand the fluid efficiently. Particularly, when the check valve (95) is provided downstream of the on-off valve (61) provided in the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205), the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) can be prevented from being a dead volume hole for the fluid in the fluid chamber (72, 82, 230), as in the fourth aspect of the present invention. This can be thus ensured, thereby expanding the fluid in the expansion mechanism (50, 100, 200) further efficiently.

[0045] In the fifth aspect of the present invention, the bypass flow rate adjusting valve (66) is provided in the bypass circuit (56) bypassing the expansion mechanism (50, 100, 200) to enable fine adjustment of the circulation amount of the fluid in the expansion mechanism (50, 100, 200) and flow rate adjustment where the flow rate of the fluid is extremely larger than that in the normal driving operation. Particularly, when the bypass flow rate adjusting valve (66) is controlled based on the pressure of the fluid introduced to the expansion mechanism (50, 100,

200), as in the sixth aspect of the present invention, the circulation amount can be adjusted so that the pressure of the expansion mechanism (50, 100, 200) is the target value.

[0046] In the seventh aspect of the present invention, the flow rate adjusting valve (60) is provided in the suction passage (24) connected to the main suction hole (55, 103, 201), so that the flow rate of the fluid introduced to the fluid chamber (72, 82, 230) of the expansion mechanism (50, 100, 200) can be adjusted to the optimum flow rate, thereby efficiently recovering the power in the expansion mechanism (50, 100, 200).

[0047] In the eighth aspect of the present invention, the flow rate adjusting valve (60) is provided downstream of the point branching apart from the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205), and accordingly, only the flow rate of the fluid introduced from the main suction hole (55, 103, 201) can be adjusted independently, thereby achieving further fine control of the fluid circulation amount in the expansion mechanism (50, 100, 200).

[0048] In the seventh and eighth aspects of the present invention, when the flow rate adjusting valve (60) is controlled based on the pressure of the fluid introduced in the expansion mechanism (50, 100, 200), especially as in the ninth aspect, the flow rate of the fluid introduced from the main suction hole (55, 103, 201) can be directly adjusted so that the pressure of the expansion mechanism (50, 100, 200) is the target value.

[0049] Further, in the tenth aspect of the present invention, the on-off valve control means (93) is provided to control the on-off valve (61) on the basis of the pressure of the fluid introduced in the expansion mechanism (50, 100, 200). Accordingly, opening/closing control on the on-off valve (61) can increase/decrease the fluid circulation amount in the expansion mechanism (50, 100, 200) to the optimum flow rate, thereby achieving efficient power recovery in the expansion mechanism (50, 100, 200).

[0050] In the eleventh aspect of the present invention, the on-off valve control means (93) is so configured to sequentially open the on-off valves (61) so that the suction passages (27) communicate sequentially with the fluid chamber (72, 82, 230) through the auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) when the pressure is larger than the target value. Hence, the flow rate of the fluid can be increased quickly and reliably up to the flow rate necessary in the expansion mechanism (50, 100, 200).

[0051] In the twelfth aspect of the present invention, the on-off valve control means (93) is so configured to control, when the pressure is smaller than the target value, the on-off valves (61) to sequentially close the auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) in the reverse order of connection from one connected to the fluid chamber (72, 82, 230) last. Hence, the fluid flow rate can be decreased quickly and reliably up to the flow rate necessary in the expansion mechanism (50, 100, 200).

[0052] In the thirteenth aspect of the present invention, the bypass flow rate adjusting valve (66) is controlled first so that the pressure is the target value. When the bypass flow rate adjusting valve (66) is at the predetermined opening, the on-off valve (61) is then opened/closed. Hence, quick and smooth adjustment of the circulation amount of the fluid in the expansion mechanism (50, 100, 200) can be achieved to achieve efficient power recovery.

[0053] In the fourteenth aspect of the present invention, where the circulation amount of the fluid in the expansion mechanism (50, 100, 200) is too large even when the on-off valves (61) and the bypass flow rate adjusting valve (66) are closed in reducing the circulation amount, the flow rate adjusting valve (60) additionally adjusts the flow rate. Hence, quick and smooth reduction in circulation amount of the fluid in the expansion mechanism (50, 10, 200) can be achieved over a wide range, thereby achieving further efficient power recovery.

[0054] According to the fifteenth aspect of the present invention, which employs a multistage rotary expansion mechanism (50, 100), blow-through of the introduced high pressure fluid can be prevented, and the expansion mechanism (50, 100) can expand the fluid efficiently. Particularly, when the two-stage rotary expansion mechanism is employed as in the sixteenth aspect of the present invention, prevention of blow-through of the high pressure fluid can be ensured, and simplification of the configuration and reduction in manufacturing cost can be achieved.

[0055] In the seventeenth aspect of the present invention, the auxiliary suction hole (56, 104, 113, 114) is formed at the angle point obtained by adding the compensation value to the angle point geometrically obtained based on a desired displacement volume. Hence, the necessary amount of the refrigerant in the fluid chamber (72, 230) can be secured with a decrease in refrigerant flow rate taken into consideration, which is caused by pressure loss when the refrigerant flows from the auxiliary suction hole (56, 104, 113, 114) to the fluid chamber (72, 230), thereby preventing excessive expansion in the expansion mechanism (50, 100). Particularly, in the eighteenth aspect of the present invention, the desired displacement volume is the displacement volume necessary in the cooling operation, and hence, prevention of excessive expansion in the expansion mechanism (50, 100) in the cooling operation can be ensured.

[0056] In the nineteenth aspect of the present invention, the expansion mechanism (200) is of scroll type, and accordingly, prevention of the fluid at a high pressure from blow-through can be ensured without necessitating multiple stages, thereby obtaining an efficient expansion mechanism (200).

[0057] In the twentieth aspect of the present invention, the fluid is CO₂ refrigerant, and the refrigerating apparatus is configured to perform the supercritical refrigeration cycle, thereby obtaining a refrigerating apparatus suitable for environment.

[0058] In addition, in the twenty-first aspect of the

present invention, the main suction hole (55, 103, 201) and the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) are formed in the expansion mechanism to obtain an expander exhibiting the same advantages as those in the first aspect.

5

BRIEF DESCRIPTION OF THE DRAWINGS

[0059]

[FIG. 1] FIG. 1 illustrates a schematic configuration of a refrigerant circuit for an air conditioner, in accordance with Example Embodiment 1.

[FIG. 2] FIG. 2 is a vertical cross-sectional view of a compression/expansion unit.

[FIG. 3] FIG. 3 is an enlarged cross-sectional view showing a vertical section of an expansion mechanism.

[FIG. 4] FIG. 4 is an enlarged cross-sectional view showing a transverse section of a main part of the expansion mechanism.

[FIG. 5] FIG. 5 is a cross-sectional view showing the states of main parts of rotary mechanisms of the expansion mechanism where a crankshaft rotates 90 degrees by 90 degrees, in accordance with Example Embodiment 1.

[FIG. 6] FIG. 6 graphs relationships between the suction volume and the pressure of refrigerant in the expansion mechanism.

[FIG. 7] FIG. 7 is a diagram corresponding to FIG. 6 for comparing the present invention with the case of injection.

[FIG. 8] FIG. 8 is a view showing a schematic configuration of a controller controlling valves.

[FIG. 9] FIG. 9 is a flowchart depicting a control flow for the valves.

[FIG. 10] FIG. 10 is a table indicating one example of valve control.

[FIG. 11] FIG. 11 schematically graphs a relationship between the total opening of the valves and the refrigerant circulation amount in the expansion mechanism.

[FIG. 12] FIG. 12 graphs examples of a relationship between the suction volume and the pressure of the refrigerant where a plurality of suction ports are opened.

[FIG. 13] FIG. 13 is a view corresponding to FIG. 3, in accordance with Modified Example 1 of Example Embodiment 1.

[FIG. 14] FIG. 14 is a view corresponding to FIG. 4, in accordance with Modified Example 2 of Example Embodiment 1.

[FIG. 15] FIG. 15 is a transverse cross-sectional view showing the states where an orbit scroll of an expansion mechanism rotates 60 degrees by 60 degrees, in Example Embodiment 2.

[FIG. 16] FIG. 16 graphs examples of a relationship between the angle point of a second suction port and

the refrigerant flow rate.

[FIG. 17] FIG. 17 is a table indicating calculation results of the angle point of the second suction port where the performance of a heat exchanger is changed.

INDEX OF REFERENCE NUMERALS

[0060]

10

15

20

25

30

35

40

45

50

55

1 air conditioner (refrigerating apparatus)

10 refrigerant circuit

20 compression/expansion unit

24 first inflow pipe (suction passage)

27 second inflow pipe (suction passage)

40 compression mechanism

50 expansion mechanism

55 first suction port (main suction hole)

56 second suction port (auxiliary suction hole)

59 expansion chamber

60 pre-throttle valve (flow rate adjusting valve)

61 on-off valve

65 bypass pipe (bypass circuit)

66 bypass valve (bypass flow rate adjusting valve)

70 first rotary mechanism section

71 first cylinder (first member)

72 first fluid chamber (fluid chamber)

75 first piston (second member)

80 second rotary mechanism section

81 first cylinder (first member)

82 second fluid chamber (fluid chamber)

85 second piston (second member)

90 pressure detecting means

92 pre-throttle valve flow rate control section (flow rate control means)

93 on-off control section (on-off valve control means)

94 bypass valve flow rate control section (bypass flow rate control means)

95 check valve

100 expansion mechanism

101 first rotary mechanism section

102 first cylinder (first member)

103 first suction port (main suction hole)

104 second suction port (auxiliary suction hole)

111 second rotary mechanism section

112 second cylinder (first member)

113 third suction port (auxiliary suction hole)

114 fourth suction port (auxiliary suction hole)

116 second piston (second member)

121 third rotary mechanism section

122 third cylinder (first member)

124 third piston (second member)

200 scroll mechanism (expansion mechanism)

201 suction port (main suction hole)

203 second suction port (auxiliary suction hole)

204 third suction port (auxiliary suction hole)

205 fourth suction port (auxiliary suction hole)

210 orbiting scroll (first member, scroll member)

- 211 orbiting side wrap (wrap)
- 220 fixed scroll (second member, scroll member)
- 221 fixed side wrap (wrap)
- 230 fluid chamber
- 231 A chamber (fluid chamber)
- 232 B chamber (fluid chamber)

BEST MODE FOR CARRYING OUT THE INVENTION

[0061] Example embodiments of the present invention will be described below with reference to the accompanying drawings. The following preferable embodiments describe substantially mere examples, and are not intended to limit the scope of the present invention, applicable subjects, and use.

<Example Embodiment 1>

- Overall configuration of air conditioner -

[0062] FIG. 1 illustrates a refrigerant circuit (10) for an air conditioner (1) as a refrigerating apparatus in accordance with Example Embodiment 1 of the present invention. The air conditioner (1) includes an outdoor unit (2) and an indoor unit (3). In the outdoor unit (2), there are accommodated a compression/expansion unit (20), an outdoor heat exchanger (14), a four-way switching valve (12), and a bridge circuit (13) including check valves (11, 11, 11, 11). On the other hand, an indoor heat exchanger (15) is accommodated in the indoor unit (3). Though not shown especially, fans are provided in the heat exchangers (14, 15) to blow outdoor air or indoor air to the heat exchangers (14, 15), respectively.

[0063] The outdoor unit (2) and the indoor unit (3) are connected to each other by means of a pair of communication pipes (16, 17) to form the refrigerant circuit (10) as a closed circuit to which the compression/expansion unit (20), the heat exchangers (14, 15), and the like are connected. In the present example embodiment, carbon dioxide (CO₂) as refrigerant is filled in the refrigerant circuit (10).

[0064] The compression/expansion unit (20) includes a casing (21) is a hermetic container in a vertically oblong cylindrical shape. In the casing (21), a compression mechanism (40), an expansion mechanism (50), and a motor (26) are accommodated. Specifically, the compression mechanism (40), the motor (26), and the expansion mechanism (50) are arranged in this order from below to above in the casing (21). Though the details of the compression/expansion unit (20) will be described later, the present invention provides a feature that suction ports (55, 56) as a plurality of suction holes are formed in the expansion mechanism (50) so that the suction amount of the refrigerant is variable. FIG. 1 shows the case where two suction ports are formed in the expansion mechanism (50) as one example.

[0065] Herein, an accumulator (18) is provided on the suction side of the compression mechanism (40) of the

compression/expansion unit (20) in the refrigerant circuit (10). A pre-throttle valve (60) and an on-off valve (61) are provided correspondingly to the plurality of suction ports (55, 56) on the suction side of the expansion mechanism (50). Specifically, the pre-throttle valve (60) is provided in a suction passage connected to the first suction port (55), which is first connected to a fluid chamber (72) in the suction stroke of the expansion mechanism (50), and the on-off valve (61) is provided in a suction passage connected to the second suction port (56), which is secondly connected to the fluid chamber (72). The pre-throttle valve (60), the first suction port (55), and the second suction port (56) correspond to a flow rate adjusting valve, a main suction hole, and an auxiliary suction hole in the present invention, respectively.

[0066] Further, in the refrigerant circuit (10), a bypass pipe (65) forming a bypass circuit is provided to bypass the suction side and the discharge side of the expansion mechanism (50). In the bypass pipe (65), a bypass valve (66) is provided as a bypass flow rate adjusting valve in the present invention. The bypass valve (66) adjusts the flow rate of the refrigerant in the bypass pipe (65) to adjust the flow rate of the refrigerant flowing to the expansion mechanism (50).

[0067] The heat exchangers (14, 15) are cross-fin type fin-and-tube heat exchangers. The outdoor heat exchanger (14) performs heat exchange between the refrigerant circulating in the refrigerant circuit (10) and the outdoor air, while the indoor heat exchanger (15) performs heat exchange between the refrigerant circulating in the refrigerant circuit (10) and the indoor air.

[0068] The four-way switching valve (12) includes four ports. The first port of the four-way switching valve (12) is connected to the discharge side of the compression mechanism (40). The second port is connected to one end of the indoor heat exchanger (15). The third port is connected to one end of the outdoor heat exchanger (14). The fourth port is connected to the suction side of the compression mechanism (40).

[0069] The four-way switching valve (12) is configured to be switched between the state in which the first port communicates with the second port while the third port communicates with the fourth port (the state indicated by the solid lines in FIG. 1) and the state in which the first port communicates with the third port while the second port communicates with the fourth port (the state indicated by the broken lines in FIG. 1).

[0070] The bridge circuit (13) is a combination of the four check valves (11, 11, 11, 11) forming a bridge, and is configured to allow the refrigerant to flow always in one direction to the expansion mechanism (50) even when the refrigerant flow in the refrigerant circuit (10) is reversed by the operation of the four-way switching valve (12). This can eliminate the need to control the four-way switching valve, when compared with the case where one four-way switching valve is provided in addition to the four-way switching valve (12), to simplify the configuration. The present example embodiment provides, but

is not limited to, the bridge circuit (13) formed by the check valves (11, 11, 11, 11), and may provide one additional four-way switching valve.

- Configuration of compression/expansion unit -

[0071] As shown in FIG. 2, the compression/expansion unit (20) includes the casing (21) as a hermetic container in a vertically oblong cylindrical shape. The compression mechanism (40), the motor (26), and the expansion mechanism (50) are arranged in this order from below to above inside the casing (21). Further, suction pipes (22), a discharge pipe (23), inflow pipes (24, 27) each forming a part of the suction passages in the present invention, and an outflow pipe (25) are formed to pass through the casing (21). The suction pipes (22) are connected to the compression mechanism (40), and the inflow pipes (24, 27) and the out-flow pipe (25) are connected to the expansion mechanism (50). The discharge pipe (23) has one end opening to a space between the motor (26) and the expansion mechanism (50) in the casing (21). A first inflow pipe (24) of the inflow pipes (24, 27) is connected to the first suction port (55), while a second inflow pipe (27) thereof is connected to the second suction port (56). That is, the pre-throttle valve (60) is provided downstream of a point branching into the first inflow pipe (24) apart from the second inflow pipe (27) outside the casing (21). The on-off valve (61) is provided downstream of a point branching into the second inflow pipe (27) apart from the first inflow pipe (24) outside the casing (21). Thus, the pre-throttle valve (60) on the downstream side of the point branching apart from the second inflow pipe (27) can adjust only the flow rate of the refrigerant introduced to the expansion mechanism (50) from the first inflow pipe (24), namely, the first suction port (55), thereby enabling fine adjustment of the flow rate.

[0072] The compression mechanism (40) is a swing piston type rotary compressor. The compression mechanism (40) includes two cylinders (41, 42) and two pistons (47, 47). A rear head (44), a first cylinder (41), an intermediate plate (46), a second cylinder (42), and a front head (45) are stuck in this order from below to above in the compression mechanism (40).

[0073] In the compression mechanism (40), a first crankshaft (31) is provided to be connect to and drive the motor (26). The first crankshaft (31) is arranged so as to pass at its lower part through the rear head (44), the first cylinder (41), the intermediate plate (46), the second cylinder (42), and the front head (45).

[0074] Specifically, two compression side eccentric parts (32, 33) are arranged side by side in the axial direction at the lower part of the crankshaft (31). The compression side eccentric parts (32, 33) have axial centers eccentric from the axial center of the first crankshaft (31). The eccentric direction of a lower first compression side eccentric part (32) is displaced by 180 degrees relative to that of an upper second compression side eccentric part (33). The first compression side eccentric part (32)

and the second compression side eccentric part (33) are disposed inside the first cylinder (41) and the second cylinder (42), respectively.

[0075] The cylindrical pistons (47, 47) are fitted around the first and second compression side eccentric parts (32, 33), respectively. The pistons (47, 47) are disposed in the first and second cylinders (41, 42) one by one to form compression chambers (43, 43) between the outer peripheral surfaces of the pistons (47, 47) and the inner peripheral surfaces of the cylinders (41, 42). Though not shown especially, plate-shaped blades protrude at the side surface of the pistons (47) to extend radially outward, and are supported by the cylinders (41, 42) via swing bushes.

[0076] An engagement hole (34) is formed in the upper end surface of the first crankshaft (31). The engagement hole (34) is a hexagonal hole in section extending downward along the axial center of the first crankshaft (31), and is in engagement with an engagement protrusion (38) formed at the lower end part of a second crankshaft (35), which will be described later.

[0077] In the first and second cylinders (41, 42), suction ports (48) are formed one by one. The suction ports (48) pass radially through the cylinders (41, 42). One ends of the suction ports (48) open at the inner peripheral surfaces of the cylinders (41, 42) to be connected to the compression chambers (43), while the other ends thereof are connected to the suction pipes (22).

[0078] In the front head (44) and the rear head (45), discharge ports are formed one by one. A discharge port formed in the front head (44) allows the compression chamber (43) in the second cylinder (42) to communicate with the internal space of the casing (21). On the other hand, a discharge port formed in the rear head (45) allows the compression chamber (43) in the first cylinder (41) to communicate with the internal space of the casing (21). Discharge valves of reed valves are provided at the terminal ends of the discharge ports to open/close the discharge ports. With this configuration, the gas refrigerant discharged to the internal space of the casing (21) from the compression mechanism (40) is sent out from the compression/expansion unit (20) through the discharge pipe (23). In FIG. 2, the discharge ports and the discharge valves are not shown.

[0079] The compression mechanism (40) is fixed to the casing (21) by means of a ring-shaped mounting plate (49). Specifically, the mounting plate (49) is fixed at its outer peripheral surface to the inner surface of the casing (21) by welding, and the front head (44) of the compression mechanism (40) is fixed to the mounting plate (49) by fastening a bolt (not shown).

[0080] The motor (26) is disposed in the central part in the longitudinal direction of the casing (21). The motor (26) includes a stator (27) and a rotor (28). The stator (27) is fixed at its outer peripheral surface to the inner peripheral surface of the casing (21). The rotor (28) is disposed inside the stator (27), and the upper part of the first crankshaft (31) passes through the rotor (28).

[0081] As shown in FIGS. 4 and 5, the expansion mechanism (50) is a so-called swing piston type rotary expander, and two pairs of cylinders (71, 81) as first members and pistons (75, 85) as second members are provided in the expansion mechanism (50). The expansion mechanism (50) also includes a front head (51), an intermediate plate (53), and a rear head (52). In the expansion mechanism (50), the cylinders (71, 81), the front head (51), the intermediate plate (53), and the rear head (52) serve as fixed members, while the pistons (75, 85) serve as orbiting members.

[0082] In the expansion mechanism (50), the front head (51), a first cylinder (71), the intermediate plate (53), a second cylinder (81), and the rear head (52) are stuck in this order from blow to above. In this state, the first cylinder (71) is blocked at its lower end surface by the front head (51), and is blocked at its upper end surface by the intermediate plate (53). On the other hand, the second cylinder (81) is blocked at its lower end surface by the intermediate plate (53), and is blocked at its upper end surface by the rear head (52).

[0083] The cylinders (71, 81) are thick plates almost in ring shapes. The inner diameter of the second cylinder (81) is larger than that of the first cylinder (71). The thickness (the height) of the second cylinder (81) is larger than that of the first cylinder (71).

[0084] In the expansion mechanism (50), the second crankshaft (35) is provided to pass through the front head (51), the first cylinder (71), the intermediate plate (53), the second cylinder (81), and the rear head (52). The engagement protrusion (83) protrudes at the lower end surface of the second crankshaft (35). The engagement protrusion (38) is a hexagonal column-shaped protrusion extending downward from the lower end surface of the second crankshaft (35). The sectional shape of the engagement protrusion (38) is a hexagon corresponding to the sectional shape of the engagement hole (34) of the first crankshaft (31). The first crankshaft (31) and the second crankshaft (35) are connected in such a manner that the engagement protrusion (38) of the second crankshaft (35) is inserted in the engagement hole (34) of the first crankshaft (31), thereby forming a single shaft (30).

[0085] At the upper part of the second crankshaft (35), two expansion side eccentric parts (36, 37) are formed correspondingly to the cylinders (71, 81). The axial centers of the two expansion side eccentric parts (36, 37) are eccentric from the axial center of the second crankshaft (35). The eccentric direction of a lower first expansion side eccentric part (36) agrees with that of an upper second expansion side eccentric part (37) with respect to the axial center of the second crankshaft (35). It should be noted that the eccentric amount of the second expansion side eccentric part (37) is larger than that of the first expansion side eccentric part (36). The first expansion side eccentric part (36) and the second expansion side eccentric part (37) are disposed inside the first cylinder (71) and the second cylinder (81), respectively.

[0086] The cylindrical pistons (75, 85) are fitted around

the first and second expansion side eccentric parts (36, 37), respectively. A first piston (75) fitted around the first expansion side eccentric part (36) is disposed inside the first cylinder (71), while a second piston (85) fitted around the second expansion side eccentric part (37) is disposed inside the second cylinder (81).

[0087] As shown in FIG. 4, the first piston (75) is slidably in contact with the inner peripheral surface of the first cylinder (71) at its outer peripheral surface, the front head (75) at its lower end surface, and the intermediate plate (53) at its upper end surface. With this configuration, a first fluid chamber (72) is formed between the inner peripheral surface of the first cylinder (71) and the outer peripheral surface of the first piston (75) in the first cylinder (71).

[0088] On the other hand, the second piston (85) is slidably in contact with the inner peripheral surface of the second cylinder (81) at its outer peripheral surface, the intermediate plate (53) at its lower end surface, and the rear head (52) at its upper end surface. With this configuration, a second fluid chamber (82) is formed between the inner peripheral surface of the second cylinder (81) and the outer peripheral surface of the second piston (85) in the second cylinder (81).

[0089] Blades (76, 86) are provided at the first and second pistons (75, 85) one by one. The blades (76, 86) are formed in a plate shape extending radially outward from the outer peripheral surfaces of the pistons (75, 85).

[0090] Pairs of bushes (77, 78) are provided one by one at the cylinders (71, 81). The bushes (77, 78) are small pieces having flat inside surfaces and arc-shaped outside surfaces. The pairs of bushes (77, 78) sandwich the blades (76, 86) so as to slide at their inside surfaces on the blades (76, 86) and slide at their outside surfaces on the cylinders (71, 81). Accordingly, the blades (76, 86) integrally formed with the pistons (75, 85) are supported by the cylinders (71, 81) via the bushes (77, 78) to be rotatable about and movable in a back and forth direction relative to the cylinders (71, 81).

[0091] The first fluid chamber (72) in the first cylinder (71) is partitioned by a first blade (76). The left side of the first blade (76) in FIG. 4 serves as a first high pressure chamber (73) on the high pressure side, while the right side thereof serves as a first low pressure chamber (74) on the low pressure side. Similarly, the second fluid chamber (82) in the second cylinder (81) is partitioned by the second blade (86). The left side of the second blade (86) in FIG. 4 serves as a second high pressure chamber (83) on the high pressure side, while the right side thereof serves as a second low pressure chamber (84) on the low pressure side.

[0092] The first cylinder (71) and the second cylinder (81) are disposed so that the positions in the peripheral direction of the bushes (77, 78) agree with each other. In other words, the arrangement angle of the second cylinder (81) relative to the first cylinder (71) is zero degree. As described above, the first expansion side eccentric part (36) and the second expansion side eccentric part

(37) are eccentric in the same direction with respect to the axial center of the second crankshaft (35). Accordingly, at the same time when the first blade (76) is located the most outward of the first cylinder (71), the second blade (86) is located the most outward of the second cylinder (81).

[0093] In the intermediate plate (53), a communication passage (54) is formed to pass through the plate (53) in the thickness direction thereof. In the surface of the intermediate plate (53) on the side of the first cylinder (71), one end of the communication passage (54) opens on the right side of the first blade (76) in FIG. 4. On the other hand, the other end of the communication passage (54) opens on the left side of the second blade (86) in the surface of the intermediate plate (53) on the side of the second cylinder (81). That is, the communication passage (54) allows the first low pressure chamber (74) to communicate with the second high pressure chamber (83). Thus, the first low pressure chamber (74) and the second high pressure chamber (83) communicating with each other through the communication passage (54) form a single expansion chamber (59).

[0094] In the second cylinder (81), an outflow port (57) is formed. The outflow port (57) opens at a part slightly right of the bush (87) in FIG. 4 in the inner peripheral surface of the second cylinder (81) to be connected to the second low pressure chamber (84). As shown in FIGS. 1, 2, and 4, the outflow port (57) is connected to the outflow pipe (25).

[0095] Referring to one of significant features of the present invention, the first and second suction ports (55, 56) are formed in the front head (51) for introducing the refrigerant into the first fluid chamber (72) of the first cylinder (71). The suction ports (55, 56) extend radially inward from the outer peripheral surface of the front head (51), and its terminal end bends upward to open at the upper surface of the front head (51), as shown in FIG. 3. That is, when viewing the first fluid chamber (72) from above in FIG. 4, the first suction port (55) extends radially and opens at a point slightly left of the bush (77), and the second suction port (56) extends radially and opens at a point that forms a predetermined angle (e.g., 160 degrees) with respect to the first suction port so as to be almost opposed to the first suction port (55). The angle point of the second suction port (56) will be described in detail later.

[0096] Herein, the first suction port (55) and the second suction port (56) are connected to the first inflow pipe (24) in which the pre-throttle valve (60) is provided and the second inflow pipe (27) in which the on-off valve (61) is provided, respectively.

[0097] As described above, a plurality of suction ports (55, 56) for introducing the refrigerant into the first fluid chamber (72) facilitates adjustment of the introduction amount of the refrigerant to the fluid chamber (72). Specifically, where only the first suction port (55) causes shortage of the refrigerant circulation amount (mass flow rate; hereinafter, the same is applied), the refrigerant is

introduced additionally from the second suction port (56) to secure the refrigerant circulation amount necessary in the expansion mechanism (50).

[0098] Further, as described above, the suction ports (55, 56) are connected from below to the first fluid chamber (72). When, for example, the on-off valve (61) is closed so as not to introduce the refrigerant from the second suction part (56), the refrigerating machine oil in the fluid chamber (72) can stay in the second suction port (56) to fill the space thereof. This can prevent the refrigerant from entering the second suction port (56). That is, with the above configuration, the second suction port (56) is prevented from being a dead volume port, thereby efficiently expanding the refrigerant in the expansion mechanism (50).

[0099] Herein, in the expansion mechanism (50) configured as above, the first cylinder (71), the first bush (77), the front head (51) and the intermediate plate (53) blocking the respective ends of the first cylinder (71), the first piston (75), and the first blade (76) form a first rotary mechanism section (70). As well, the second cylinder (81), the second bush (87), the intermediate plate (53) and the rear head (52) blocking the respective ends of the second cylinder (81), the second piston (85), and the second blade (86) form a second rotary mechanism section (80).

[0100] That is, the expansion mechanism (50) is a two-stage rotary expander including the first rotary mechanism section (70) and the second rotary mechanism section (80). Accordingly, the suction ports are not connected to the outflow port through the fluid chambers unlike a single-stage rotary expander, and therefore, the high pressure refrigerant introduced from the suction ports can be prevented from blow-through to the outflow port. Particularly, where a single-stage one has a plurality of suction ports as in the present example embodiment, the suction ports can be connected to the outflow port. However, two or more stages for independently performing the suction stroke and the discharge stroke ensure prevention of blow-through of the high pressure refrigerant, and hence, the high pressure refrigerant can be expanded sufficiently in the expansion chamber (59).

[0101] It is noted that the expansion mechanism (50) is fixed to the casing (21) through a ring-shaped mounting plate (58), similarly to the compression mechanism (40). Specifically, the mounting plate (58) is fixed at its outer peripheral surface to the inner surface of the casing (21) by welding, and the front head (51) of the expansion mechanism (50) is fixed to the mounting plate (58) by means of a bolt (not shown).

- Angle point of second suction port -

[0102] How to determine the angle point of the second suction port (56) in the expansion mechanism (50) will be described below in detail on the assumption that the location of the blades (76, 86) is zero degree.

[0103] As described above, the second suction port

(56) in addition to the first suction port (55) can allow much more amount of refrigerant to flow into the first fluid chamber (72). Since the volumes of the fluid chambers (72, 82) connected to the second suction port (56) change according to the angle point where the second suction port (56) is formed, the displacement volume at refrigerant suction can be obtained geometrically from the volume change. Specifically, as indicated by the bold solid line, for example, in FIG. 16, the inflow amount of the refrigerant to the expansion mechanism (50) according to the angle point of the second suction port (56) can be calculated geometrically.

[0104] However, because the geometrically obtained refrigerant inflow amount does not take account of the pressure loss caused by suction in the second suction port (56), the actual refrigerant inflow amount is smaller than the geometrically obtained refrigerant inflow amount. That is, as shown in FIG. 16, the actual measurement values (black triangles) of the refrigerant inflow amount are smaller than the geometrically obtained ideal refrigerant inflow amounts by the pressure loss, which is caused when the refrigerant flows into the first fluid chamber (72) from the second suction port (56). As can be understood from FIG. 16, where the second suction port (56) is formed at an angle point where the volume change of the fluid chambers (72, 82) connected to the second suction port (56) is comparatively large, the influence of the pressure loss by suction in the second suction port (56) becomes severe. Accordingly, the actual refrigerant inflow amounts (black triangles) are greatly smaller than the geometrically obtained refrigerant inflow amounts (bold solid line).

[0105] In view of this, in the present example embodiment, a compensation value is added to the angle point corresponding to the geometrically obtained refrigerant inflow amount with a decrease in refrigerant inflow amount taken into consideration which is caused by the pressure loss at refrigerant suction as above, so that the second suction port (56) can be formed at an angle point corresponding to the actual refrigerant inflow amount.

[0106] In the present example embodiment, the expansion mechanism (50) is set at the optimum expansion ratio in the rated heating operation, and accordingly, the pressure on the low pressure side is higher in the rated cooling operation than in the rated heating operation, as will be described later in detail. Hence, it is needed to increase the inflow rate of the high pressure refrigerant in the rated cooling operation. For this reason, the position of the second suction port (56) must be set so that the necessary inflow amount of the refrigerant can be supplied from the second suction port (56) in the rated cooling operation.

[0107] FIG. 17 indicates calculation examples of the angle point of the second suction port (56). In FIG. 17, the performances of the outdoor heat exchanger (14) (outdoor heat exchange) and the indoor heat exchanger (15) (indoor heat exchange) of the air conditioner (1) were changed (enhanced or degraded) based on the actual

measurement values, and the angle points of the second suction port (56) that can secure the refrigerant flow rate necessary in the rated heating operation and the rated cooling operation in the respective cases were obtained. Herein, in FIG. 17, the term, "high pressure" means the discharge pressure of the compression mechanism (40), and the term, "low pressure" means the suction pressure of the compression mechanism (40). The temperature at the outlet of the gas cooler is nearly equal to that of the inlet of the expansion mechanism (50).

[0108] As indicated in FIG. 17, in the calculation examples, the expansion ratio in the rated heating operation ranges between 2.7 and 3.0, while the displacement volume necessary in the rated cooling operation is 1.3 to 1.6 times those (this ratio is called displacement volume ratio). The angle point of the second suction port (56) geometrically obtained from the displacement volume ratio necessary in the rated cooling operation and the expansion ratio was calculated based on the bold solid line in FIG. 16.

[0109] On the other hand, the angle point of the second suction port (56) for obtaining the displacement volume necessary in the rated cooling operation was obtained using the approximate curve (the fine solid line) of the actual measurement values in FIG. 16, which resulted in the values indicated in the right end column in FIG. 17.

[0110] Accordingly, as indicated in FIG. 17, addition of a compensation value of approximately 50 to 65 degrees to the geometrically obtained angle point of the second suction port (56) can result in an angle point where the displacement volume necessary in the rated cooling operation can be obtained. Approximately 60 degrees may be added to the geometrically obtained angle point of the second suction port (56) for compensation. Even in this case, the refrigerant flow rate more approximate to the necessary flow rate can be obtained when compared with the case with no angle compensation.

[0111] Even in the case under different conditions (different refrigerant flow rates), when the geometrically obtained angle point of the second suction port (56) is compensated (indicated by the fine broken line) with the pressure loss, which is caused by suction at the second suction port (56), taken into consideration, the compensation results almost agree with the actual measurement values (white triangles), as understood from FIG. 16 showing the relationship (indicated by the bold broken line) between the geometrically obtained angle point of the second suction port (56) and the refrigerant flow rate. Accordingly, the above compensation can obtain the angle point of the second suction port (56) with sufficiently high accuracy. In the present example embodiment, it is preferable as apparent from FIG. 16 that the angle point of the second suction port (56) is set larger than 120 degrees where the refrigerant flow rate is changed 10 % or more. More preferably, it is set in the range between 150 and 200 degrees, as indicated in FIG. 17.

- Driving operation -

[0112] An operation of the air conditioner (1) will be described next. Herein, a cooling operation and a heating operation will be described first, and an operation of the expansion mechanism (50) will be described next.

<Cooling operation>

[0113] In the cooling operation, the four-way switching valve (12) is switched to the state indicated by the broken lines in FIG. 1. In this state, when the motor (26) of the compression/expansion unit (20) is conducted, the refrigerant circulates in the direction of the broken arrows in the refrigerant circuit (10) to perform a vapor compression refrigeration cycle.

[0114] The refrigerant compressed in the compression mechanism (40) passes through the discharge pipe (23), and then is discharged from the compression/expansion unit (20). In this state, the pressure of the refrigerant is higher than the critical pressure. This discharged refrigerant is sent to the outdoor heat exchanger (14) to dissipate heat to the outdoor air.

[0115] The high pressure refrigerant having dissipated heat in the outdoor heat exchanger (14) flows into the expansion mechanism (50) through the inflow pipes (24, 27). In the expansion mechanism (50), the high pressure refrigerant is expanded, and the power is recovered from this high pressure refrigerant. The low pressure refrigerant after expanded is sent to the indoor heat exchanger (15) through the outflow pipe (25).

[0116] In the indoor heat exchanger (15), the refrigerant flowing therein absorbs heat from the indoor air to be evaporated, thereby cooling the indoor air. The low pressure gas refrigerant flowing out from the indoor heat exchanger (15) passes through the suction pipes (22), and then is sucked into the compression mechanism (40). The compression mechanism (40) compresses the sucked refrigerant again and discharges it.

<Heating operation>

[0117] In the heating operation, the four-way switching valve (12) is switched to the state indicated by the solid lines in FIG. 1. In this state, when the motor (26) of the compression/expansion unit (20) is conducted, the refrigerant circulates in the direction of the solid arrows in the refrigerant circuit (10) to perform a vapor compression refrigeration cycle.

[0118] The refrigerant compressed in the compression mechanism (40) passes through the discharge pipe (23), and then is discharged from the compression/expansion unit (20). In this state, the pressure of the refrigerant is higher than the critical pressure. This discharged refrigerant is sent to the indoor heat exchanger (15) to dissipate heat to the indoor air, thereby heating the indoor air.

[0119] The refrigerant having dissipated heat in the indoor heat exchanger (15) flows into the expansion mechanism (50) through the inflow pipes (24, 27).

In the expansion mechanism (50), the high pressure refrigerant is expanded, and the power is recovered from this high pressure refrigerant. The low pressure refrigerant after expanded is sent to the outdoor heat exchanger (14) through the outflow pipe (25), and absorbs heat from the outdoor air to be evaporated. The low pressure gas refrigerant flowing out from the outdoor heat exchanger (14) passes through the suction pipes (22), and then is sucked into the compression mechanism (40). The compression mechanism (40) compresses the sucked refrigerant again and discharges it.

<Operation of expansion mechanism>

[0120] The operation of the expansion mechanism (50) will be described with reference to FIG. 5.

[0121] First described is a process that the high pressure refrigerant in the supercritical state flows into the first high pressure chamber (73) of the first rotary mechanism section (70). When the second crankshaft (35) rotates slightly from the rotation angle of 0 degree, the contact point between the first piston (75) and the first cylinder (71) passes the opening of the first suction port (55) to allow the high pressure refrigerant to start flowing into the first high pressure chamber (73) from the first suction port (55). Thereafter, as the rotation angle of the second crankshaft (35) is gradually increased to 60 degrees, 180 degrees, and then 270 degrees, the high pressure refrigerant flows into the first high pressure chamber (73). This flowing of the high pressure refrigerant from the first suction port (55) into the first high pressure chamber (73) continues until the rotation angle of the second crankshaft (35) reaches approximately 360 degrees (until the first suction port is closed).

[0122] In so doing, where the on-off valve (61) is opened, when the rotation angle of the second crankshaft (35) reaches a predetermined angle (for example, 160 degrees in the present example embodiment), and the contact point between the first piston (75) and the first cylinder (71) passes the opening of the second suction port (56), the high pressure refrigerant starts flowing into the first high pressure chamber (73) additionally from the second suction port (56). This flowing of the high pressure refrigerant from the second suction port (56) into the first high pressure chamber (73) continues until the second suction port is closed.

[0123] Accordingly, until the rotation angle of the second crankshaft (35) exceeds 360 degrees, and reaches the angle where the second suction port (56) is closed (520 degrees in the present example embodiment), the high pressure refrigerant flows into the first high pressure chamber (73) from the first and second suction ports (55, 56). This means extension of the suction stroke when compared with a conventional configuration with only the first suction port (55), thereby enabling introduction of much more amount of the high pressure refrigerant.

[0124] Next, a process that the refrigerant is expanded

in the expansion mechanism (50) will be described. As shown in FIG. 5, when the second crankshaft (35) rotates slightly from 0 degree (360 degrees), the first high pressure chamber (73) of the first cylinder (71) communicates with the second high pressure chamber (83) of the second cylinder (81) through the communication passage (54) to allow the refrigerant to start flowing from the first high pressure chamber (73) to the second high pressure chamber (83). As described above, during the time when the high pressure refrigerant flows into the first high pressure chamber (73) from the second suction port (56), the refrigerant is hardly expanded in the first high pressure chamber (73) and the second high pressure chamber (83). After the second suction port (56) is closed (after the rotation angle reaches approximately 520 degrees), as the rotation angle of the second crankshaft (35) is increased to 540 degrees, then to 630 degrees, the volume of the first high pressure chamber (73), that is, the first low pressure chamber (74) gradually decreases, while the volume of the second high pressure chamber (83) gradually increases. As a result, the volume of the expansion chamber (59) gradually increases. The increase in volume of the expansion chamber (59) continues until the time immediately before the rotation angle of the second crankshaft (35) reaches 720 degrees. In the process that the volume of the expansion chamber (59) increases, the refrigerant in the expansion chamber (59) is expanded to drive and rotate the second crankshaft (35). In this way, the refrigerant in the first low pressure chamber (74) expands and flows into the second high pressure chamber (83) through the communication path (54).

[0125] The process that the refrigerant flows out from the second low pressure chamber (84) of the second rotary mechanism section (80) will be described next. When the refrigerant is expanded in the second high pressure chamber (83), the second high pressure chamber (83) starts being connected to the outflow port (57) from the time point when the rotation angle of the second crankshaft (35) reaches 720 degrees, to serve as the second low pressure chamber (84). That is, the refrigerant starts flowing out from the second low pressure chamber (84) to the outflow port (57). Thereafter, the rotation angle of the second crankshaft (35) is increased to 810 degrees, 900 degrees, and then 990 degrees. During the time until the rotation angle reaches 1080 degrees, the low pressure refrigerant after expanded flows out from the second low pressure chamber (84).

[0126] FIG. 6 shows the relationship between change in suction volume and change in pressure of the expansion chamber (59) in the expansion mechanism (50). In FIG. 6, the broken line indicates a graph where the high pressure refrigerant is introduced from only the first suction port (55) with no excessive expansion caused. The fine solid line indicates a graph where the high pressure refrigerant is introduced from only the first suction port (55) with excessive expansion caused. The bold solid line indicates a graph where the high pressure refrigerant

is introduced additionally from the second suction port (56).

[0127] For example, where no excessive expansion is caused in the expansion mechanism (50) (the case indicated by the broken line in FIG. 6), the high pressure refrigerant in the supercritical state flows into the first high pressure chamber (73) during the time between the point a and the point b. Then, the first high pressure chamber (73) is connected to the communication passage (54) to be switched to the first low pressure chamber (74). In the expansion chamber (59) formed with the first low pressure chamber (74) and the second high pressure chamber (83), the high pressure refrigerant therein drops in pressure sharply in the time between the point b and the point c to be in a saturated state. The refrigerant in the saturated state is expanded, while part thereof is evaporated, so that the pressure thereof gently reduces until the point d. Then, the second high pressure chamber (83) is connected to the outflow port (57) to be switched to the second low pressure chamber (84). The refrigerant in the second low pressure chamber (84) is sent to the outflow port (35) until the point e. During this time, the concentration ratio of the sucked refrigerant to the discharged refrigerant matches the designed expansion ratio, and hence, an operation with efficient power recovery can be performed.

[0128] Meanwhile, the high pressure or the low pressure may deviate from the design values due to switching between the cooling operation and the heating operation or change in outdoor temperature. Specifically, in the case where the expansion mechanism (50) is designed so that the pressure and the suction volume are changed as indicted in the broken line in FIG. 6 in the rated heating operation of the air conditioner (1), switching to the cooling operation increases the pressure on the low pressure side in the rated cooling operation up to the level indicated by the fine solid line, thereby creating an excessive expansion region (D).

[0129] In contrast, introduction of the high pressure refrigerant additionally from the second suction port (56) as described above can cause change in suction volume and pressure in the range where the region (C) indicated by the bold solid line is added to the region B in FIG. 6, thereby achieving much more power recovery.

[0130] The above configuration can perform further efficient power recovery when compared with the case where injection is performed in the conventional expansion stroke (FIG. 7). Specifically, in the configuration performing injection, the power recovery can be performed only in the region C as an advantage of the injection in addition to the region B where the power is recovered from the high pressure refrigerant introduced from the first suction port (55), as shown in FIG. 7. In contrast, as indicated by the dash-dot line in FIG. 7, the above configuration can perform recovery of further more power.

[0131] Herein, the refrigerant circuit (10) is a closed circuit, and therefore, the flow rate of the refrigerant in the expansion mechanism (50) must agree with the flow

rate of the refrigerant in the compression mechanism (40). For this reason, the air conditioner (1) in accordance with the present invention is configured so that the refrigerant circulation amount in the expansion mechanism (50) is not only merely increased as above, but also adjusted to the appropriate amount.

[0132] Control on the valves (60, 61, 66) for flow rate control of the refrigerant in the expansion mechanism (50) will be described below in detail.

<Valve control>

[0133] Control of the flow rate of the refrigerant in the expansion mechanism (50) will be described with reference to FIGS. 8 to 12, which is performed by flow rate control on the pre-throttle valve (60) provided in the first inflow pipe (24), and the bypass valve (66) provided in the bypass pipe (65), and opening/closing control on the on-off valve (61) provided in the second inflow pipe (27).

[0134] In the air conditioner (1) in accordance with the present example embodiment, as shown in FIG 8, pressure detecting means (90) is provided for detecting the pressure of the high pressure refrigerant introduced in the expansion mechanism (50). The pressure detecting means (90) includes, for example, a pressure sensor (not shown) detecting the pressure on the discharge side of the compression mechanism (40). The value of the pressure of the high pressure refrigerant detected by the pressure detecting means (90) is sent to a controller (91).

[0135] Herein, the controller (91) includes a pre-throttle valve flow rate control section (92) for controlling the flow rate through the pre-throttle valve (60), an opening/closing control section (93) for controlling opening/closing of the on-off valve (61), and a bypass valve flow rate control section (94) for controlling the flow rate through the bypass valve (66). On the basis of the pressure value detected by the pressure detecting means (90), the control sections (92, 93, 94) control the valves (60, 61, 66), respectively.

[0136] In the present invention, the pre-throttle valve flow rate control section (92) corresponds to flow rate control means. The opening/closing control section (93) corresponds to on-off valve control means. The bypass valve flow rate control section (94) corresponds to bypass flow rate control means.

[0137] Specific control on the valves (60, 61, 66) will be described below with reference to the flowchart of FIG. 9. In the initial state, the on-off valve (61) is closed.

[0138] First, when the flow in FIG. 9 starts, the pressure detecting means (90) detects the pressure of the high pressure refrigerant introduced in the expansion mechanism (50) at S1. The detected pressure value is compared with a predetermined target value (at S2). If it is larger than the target value (YES), the bypass valve (66) finely adjusts the circulation amount of the refrigerant to the expansion mechanism (50) so that the pressure value is the target value. When the opening of the bypass valve (66) reaches a predetermined value (YES at S4), the on-

off valve (61) is opened to increase the circulation amount of the refrigerant to the expansion mechanism (50) for adjusting it to the same refrigerant circulation amount as that in the compression mechanism (40) (S5). Even during the time when the on-off valve (61) is opened in this way, the bypass valve (66) performs the fine adjustment of the circulation amount. If the opening of the bypass valve (66) is smaller than the predetermined value at S4, the routine returns to S2 to increase the opening of the bypass valve (66) until the pressure value reaches the target value, or the opening of the bypass valve (66) reaches the predetermined value.

[0139] Herein, the target value is set at the pressure value where COP is maximum. The predetermined value of the opening of the bypass valve (66) corresponds to a predetermined opening in the present invention, and means the opening that the bypass valve (66) cannot be opened any more, or that the flow rate can be hardly adjusted even if the bypass valve (66) is opened further more.

[0140] On the other hand, when the pressure value is equal to or smaller than the target value (NO at S2), the routine proceeds to S6 to judge whether the pressure value is smaller than the target value. If it is judged that the pressure value is not smaller than the target value (NO at S6), which means that the pressure value is equal to the target value, the routine returns (RETURN) to START to start the flow again.

[0141] At S6, if the pressure value is judged to be smaller than the target value (YES), the bypass valve (66) starts being closed at subsequent S7 to finely adjust the circulation amount of the refrigerant to the expansion mechanism (50) so that the pressure value is the target value. If the pressure value is still smaller than the target value (YES at S8), the on-off valve (61) is closed at subsequent S9 to reduce the circulation amount of the refrigerant to the expansion mechanism (50). At this time point, the refrigerant circulation amount of the compression mechanism (40) is small, and therefore, the refrigerant circulation amount in the expansion mechanism (50) should be reduced accordingly. To do so, the circulation amount of the refrigerant to the expansion mechanism (50) is adjusted finely by the bypass valve (66).

[0142] If the pressure value is still smaller than the target value even when the on-off valve (61) is closed at S9 (YES at S10), the bypass valve (66) is fully or almost fully closed (at the predetermined opening) (S11). If the pressure value is yet smaller than the target value (YES at S12), the pre-throttle valve (60) is throttled to adjust the refrigerant circulation amount (S13). Thereafter, the routine returns (RETURN) to START to start the flow again.

[0143] On the other hand, if the pressure value is judged not to be smaller than the target value at S8, S10, or S12 (NO), which means that the pressure value is equal to the target value, the routine returns (RETURN) to START to start the flow again.

[0144] FIG. 10 indicates one example of the valve con-

trol according to the flowchart depicted in FIG. 9. FIG. 11 schematically shows the relationship between the refrigerant circulation amount in the expansion mechanism (50) and each opening of the valves (60, 61, 66). FIG. 12 shows the relationship between the suction volume and the pressure of the refrigerant where on-off valves are opened. FIGS. 10 to 12 show the case where a plurality of auxiliary suction ports are formed in the expansion mechanism (50). In that case, the number of the on-off valves increases accordingly, and therefore, only a step of opening or closing the other on-off valve(s) may be added to FIG. 9.

[0145] As indicated in FIG. 10, if the pressure value of the high pressure refrigerant is larger than the target value, the pre-throttle valve (60) is fully opened. As the routine proceeds (as the value of the step increases), the bypass valve (60) performs, when the difference between the pressure value and the target values is smaller, fine adjustment of the flow rate of the high pressure refrigerant introduced to the expansion mechanism (50) so that the pressure value is the target value. The on-off valve(s) (61) is/are opened when the opening of the bypass valve (66) is equal to or larger than the predetermined opening (80 % in the example in the drawing). In the example indicated in FIG. 10, three suction ports are formed in the expansion mechanism (50), in which an on-off valve at the second suction port and an on-off valve at a third suction port serve as a second suction valve and a third suction valve, respectively.

[0146] In reverse, when the difference from the target value gradually decreases as the pressure value decreases, the routine proceeds in a descending direction of the step number. The flow rate is controlled by the bypass valve (66) with the on-off valve(s) (61) closed. If the pressure value is still smaller than the target value, the bypass valve (66) is fully closed to allow only the pre-throttle valve (60) to adjust the refrigerant circulation amount.

[0147] Thus, as shown in FIG. 11, for increasing the refrigerant circulation amount in the expansion mechanism (50), the plurality of on-off valves are opened sequentially to increase stepwise the refrigerant circulation amount. Additionally, the bypass valve (66) adjusts the refrigerant circulation amount until all the on-off valves are opened, thereby smoothly increasing the refrigerant circulation amount. In this way, sequential opening of the plurality of on-off valves enables an increase in suction volume of the refrigerant, as shown in FIG. 12.

[0148] In reverse, for reducing the refrigerant circulation amount in the expansion mechanism (50), the on-off valves are closed sequentially to decrease the refrigerant circulation amount stepwise. Additionally, the bypass valve (66) adjusts the refrigerant circulation amount until all the on-off valves are closed, thereby smoothly decreasing the refrigerant circulation amount. Moreover, even when all the on-off valves are closed, and the bypass valve (66) is fully closed, the refrigerant circulation amount can be still adjusted by the pre-throttle valve (60).

[0149] Hence, the above described control of the refrigerant circulation amount can quickly and smoothly increase/decrease the circulation amount of the refrigerant to the expansion mechanism (50) over a wide range, thereby keeping balance to the refrigerant circulation amount in the compression mechanism (40).

- Advantages of Example Embodiment 1 -

[0150] Thus, in the present example embodiment, the first and second suction ports (55, 56) are formed in the expansion mechanism (50), and the pre-throttle valve (60) and the on-off valve (61) are provided in the first inflow pipe (24) connected to the first suction port (55) and the second inflow pipe (27) connected to the second suction port (56), respectively. This enables quick and reliable increase/decrease in amount of the high pressure refrigerant introduced to the expansion mechanism (50) according to increase/decrease in refrigerant circulation amount in the compression mechanism (40), thereby achieving efficient power recovery from the energy of the high pressure refrigerant while balancing the circulation amount of the high pressure refrigerant introduced in the expansion mechanism (50) with the refrigerant circulation amount in the compression mechanism (40).

[0151] Further, the suction ports (55, 56) are opened at the lower part of the first fluid chamber (72) to cause the refrigerating machine oil in the fluid chamber (72) to stay in the suction ports (55, 56), thereby preventing retention of the refrigerant therein. That is, formation of the suction ports (55, 56) at the lower part of the first fluid chamber (72) can prevent the suction ports (55, 56) from being dead volume ports, thereby achieving efficient expansion of the refrigerant in the expansion mechanism (50).

[0152] The bypass pipe (65) bypassing the expansion mechanism (50) and the bypass valve (66) at the bypass pipe (65) can mitigate abrupt increase/decrease of the refrigerant circulation amount which is caused by opening/closing of the on-off valve (61), with a result that the refrigerant circulation amount in the expansion mechanism (50) can be changed smoothly according to the refrigerant circulation amount in the compression mechanism (40).

[0153] Moreover, the expansion mechanism (50) is a two-stage rotary expander including the first rotary mechanism section (70) and the second rotary mechanism section (80), and therefore, the suction ports cannot be connected to the outflow port through the fluid chambers unlike the single-stage rotary expander. Hence, the high pressure refrigerant introduced from the suction ports can be prevented from blow-through to the outflow port. Accordingly, the high pressure refrigerant can be sufficiently expanded in the fluid chambers (72, 82) of the expansion mechanism (50).

[0154] In addition, the second suction port (56) is arranged at the angle point obtained by the predetermined compensation for the geometrically obtained angle point

to secure the displacement volume necessary at the rated cooling operation. This can allow the refrigerant at a necessary flow rate to flow into the fluid chamber (72) by way of compensation for the flow rate lowering caused due to the pressure loss when the refrigerant flows into the fluid chamber (72) from the second suction port (56). Hence, excessive expansion, which might be caused by shortage of the refrigerant to the expansion mechanism (50) in the cooling operation, can be prevented.

- Modified Example 1 of Example Embodiment 1 -

[0155] Difference of Modified Example 1 from Example Embodiment 1 lies in that a check valve (95) is provided in the second suction port (56) of the expansion mechanism (50), as shown in FIG. 13.

[0156] Specifically, the check valve (95), which allows only inflow of the refrigerant into the first fluid chamber (72), while not allowing the refrigerant to flow in the reverse direction, is provided in the second suction port (56). Accordingly, even in the state that the on-off valve (61) is closed to stop introducing the high pressure refrigerant from the second suction port (56), prevention of reverse flow of the refrigerant from the fluid chamber (72) can be ensured. As a result, prevention of reduction in dead volume of the second suction port (56) can be ensured to efficiently expand the refrigerant in the expansion mechanism (50).

- Modified Example 2 of Example Embodiment 1 -

[0157] Modified Example 2 is different from the above example embodiment in a point that the expansion mechanism is a three-stage rotary expander including three rotary mechanism sections, as shown in FIG. 14.

[0158] Specifically, an expansion mechanism (100) includes, in addition to a first rotary mechanism section (101) and a second rotary mechanism (111) which are almost the same as those in Example Embodiment 1, a largest-diameter third rotary mechanism section (121) thereabove.

[0159] Though not mentioned in detail because the rotary mechanism sections (101, 111, 121) have the same configuration as those in Example Embodiment 1, a first suction port (103) and a second suction port (104) are formed in a first cylinder (102) of the first rotary mechanism section (101), and a third suction port (113) and a fourth suction port (114) are formed in a second cylinder (112) of the second rotary mechanism section (111). An outflow port (123) is formed in a third cylinder (122) of the third rotary mechanism section (121).

[0160] Further, a communication passage (115) is formed between the second cylinder (112) and the third cylinder (122). Specifically, the communication passage (115) extends, in FIG. 14, from the right side of a bush (118) of a second blade (117) extending outward from the outer peripheral surface of a cylindrical second piston (116) disposed in the second cylinder (112) to the left

side of a bush (126) supporting a third blade (125) extending radially outward from a third piston (124) disposed in the third cylinder (122).

[0161] With the above configuration, the fluid chamber of the second cylinder (112) communicates with the fluid chamber of the third cylinder (122). Hence, the refrigerant is not only expanded while moving from the first cylinder (102) to the second cylinder (112) as in Example Embodiment 1, but also expanded while moving from the second cylinder (112) to the third cylinder (122).

[0162] The plurality of suction ports (103, 104, 113, 114) are formed in the expansion mechanism (100) thus configured as a three-stage rotary expander. Accordingly, efficient power recovery of the high pressure refrigerant can be achieved, similar to Example Embodiment 1, and the refrigerant circulation amount in the expansion mechanism (100) can be adjusted.

<Example Embodiment 2>

[0163] Example Embodiment 2 of the present invention will be described next in detail with reference to the drawings. Unlike Example Embodiment 1 in which the expansion mechanism (50) includes the two rotary mechanism sections (70, 80), the expansion mechanism in Example Embodiment 2 is a scroll mechanism (200), as shown in FIG. 15. The configurations other than the configuration of this expansion mechanism are the same as those in Example Embodiment 1, and therefore, description and indication thereof are omitted.

[0164] Specifically, the scroll mechanism (200) includes a fixed scroll (220) fixed to the casing (not shown), and an orbiting scroll (210) held to the casing via an Oldham ring (not shown).

[0165] The fixed scroll (220) forms a scroll member, and includes a plate-shaped fixed side end plate (not shown) and a scroll-shaped fixed side wrap (221) standing on the fixed side end plate. On the other hand, the orbiting scroll (210) forms a scroll member, and includes a plate-shaped orbiting side end plate (not shown) and a scroll-shaped orbiting side wrap (211) standing on the orbiting side end plate. The fixed side wrap (221) of the fixed scroll (220) and the orbiting side wrap (211) of the orbiting scroll (210) are in engagement with each other to form a plurality of fluid chambers (230) therebetween.

[0166] In the fixed scroll (220), a suction port (201) and an outflow port (202) are formed, and two second suction ports (203, 203), two third suction ports (204, 204), and two fourth suction ports (205, 205) are formed in addition. The suction port (201) is opened in the vicinity of the scroll start point of the fixed side wrap (221). On the other hand, the outflow port (202) is opened in the vicinity of the scroll end point of the fixed side wrap (221). The second to fourth suction ports (203, 204, 205) are formed at points which are sequentially connected to the space on the side of the scroll start point of the fixed side wrap (221) in the suction stroke, as will be described later.

[0167] Of the plurality of fluid chambers (230), the

spaces between the inside surface of the fixed side wrap (221) and the outside surface of the orbiting side wrap (211) serve as A chambers (231) as first fluid chambers (230). While, the spaces between the outside surface of the fixed side wrap (221) and the inside surface of the orbiting side wrap (211) serve as B chambers (231) as second fluid chambers (230).

[0168] When the orbiting scroll (210) revolves with respect to the fixed scroll (220), the second to fourth suction ports (203, 204, 205) start being connected to the fluid chambers (230) sequentially from the second ports (203, 203), to the third suction ports (204, 204), then to the fourth suction ports (205, 205) in this order, and are being connected to the fluid chambers (230) until fluid chambers (230) formed next start being defined into each two chambers (until the orbiting scroll (210) revolves by 540 degrees with respect to the fixed scroll (220)).

[0169] The inflow pipes connected to the second to fourth suction ports (203, 204, 205) are provided with on-off valves (not shown) configured to be opened/closed according to the high pressure (the discharge pressure of the compressor), similarly to the on-off valve (61) in Example Embodiment 1. In the present example embodiment, a pre-throttle valve is also provided in the inflow pipe connected to the suction port (201), and a bypass valve is provided in the bypass pipe bypassing the expansion mechanism. The control on these valves are the same as that in Example Embodiment 1.

- Driving operation -

[0170] An expansion operation by the scroll mechanism (200) will be described next. The following description refers to an expansion operation where the second to fourth suction ports (203, 204, 205) are to be opened because the pressure on the high pressure side is higher than the target value.

[0171] First, the high pressure refrigerant introduced from the suction port (201) flows into one fluid chamber (230) interposed between the vicinity of the scroll start point of the fixed side wrap (221) and the vicinity of the scroll start point of the orbiting side wrap (211). In other words, the high pressure refrigerant is introduced into a fluid chamber (230) from the suction port (201).

[0172] It is supposed herein, that the angle in the state that the scroll start point of the fixed side wrap (221) is in contact with the inside surface of the orbiting side wrap (211), while at the same time the scroll start point of the orbiting side wrap (211) is in contact with the inside surface of the fixed side wrap (221) in FIG. 15 is zero degree as a reference.

[0173] As the orbiting scroll (210) revolves to increase the revolution angle from 60 degrees to 360 degrees, the fluid chambers (230) expand, and are connected sequentially to the second suction ports (203, 203), the third suction ports (204, 204), and the fourth suction ports (205, 205). When the revolution angle of the orbiting scroll (210) exceeds 180 degrees, each fluid chamber (230) is

gradually partitioned into two spaces. When the revolution angle thereof reaches 360 degrees, the fluid chambers (230) are partitioned into the A chambers (231) and the B chambers (232).

[0174] Subsequently, until the revolution angle of the orbiting scroll (210) reaches 540 degrees via 420 degrees and 480 degrees, the second to fourth suction ports (203, 204, 205) are connected to the A chambers (231) and the B chambers (232) to introduce the high pressure refrigerant. That is, the range until the revolution angle reaches 540 degrees corresponds to the suction stroke.

[0175] Thereafter, when the revolution angle of the orbiting scroll (210) exceeds 540 degrees, the second to fourth suction ports (203, 204, 205) are closed against the A chambers (231) and the B chambers (232), and the volumes of the A chambers (231) and the B chambers (232) are increased, thereby starting expansion of the refrigerant in the A chambers (231) and the B chambers (232).

[0176] The expansion stroke in the A chambers (231) continues until the revolution angle of the orbiting scroll (210) reaches 1020 degrees. When the orbiting scroll (210) further rotates, the A chambers (231) are connected to the outflow port (202) to start allowing the refrigerant in the A chambers (231) to flow outside from the outflow port (202), thereby starting the discharge stroke.

[0177] On the other hand, the expansion stroke in the B chambers (232) continues until the revolution angle of the orbiting scroll (210) reaches 840 degrees. When the orbiting scroll (210) further rotates, the B chambers (232) are connected to the outflow port (202) to start allowing the refrigerant in the B chambers (232) to flow outside from the outflow port (202), thereby starting the discharge stroke.

[0178] The present example embodiment provides, but is not limited to, four kinds of suction ports. Only two suction ports may be formed as in Example Embodiment 1, or three or five or more kinds of suction ports may be formed.

- Advantages of Example Embodiment 2 -

[0179] Thus, according to the present example embodiment, even in the expansion mechanism formed with the scroll mechanism (200), formation of a plurality of suction ports (201, 203, 204, 205) can result in efficient power recovery and an increase in refrigerant circulation amount in the expansion mechanism, as in Example Embodiment 1. That is, when it is necessary to, for example, increase the refrigerant circulation amount in the expansion mechanism because the pressure value on the high pressure side is larger than the target value, introduction of the high pressure refrigerant from the suction ports (203, 204, 205) can ensure the necessary refrigerant circulation amount, thereby balancing the refrigerant circulation amount in the expansion mechanism with the refrigerant circulation amount in the compression mechanism.

<Other example embodiments>

[0180] The present invention may have the following configurations in the above example embodiments.

[0181] In Example Embodiment 1, the rotary mechanism sections (70, 80) of the expansion mechanism (50) are formed with, but are not limited to, the swing piston type rotary fluid machineries. Alternatively, each rotary mechanism section (70, 80) may be a rolling piston type rotary fluid machinery. In this case, in the rotary mechanism sections (70, 80), the blades (76, 86) are formed separately from the pistons (75, 85), and the bushes (77, 87) are omitted. The blades (76, 86) reciprocate in the radial direction of the cylinders (71, 81) following the movement of the pistons (75, 85) with their tip ends pressed against the outer peripheral surfaces of the pistons (75, 85).

[0182] Further, Example Embodiment 1 provides, but is not limited to, the two suction ports (55, 56) in the expansion mechanism (50). Alternatively, three or more suction ports may be formed. Moreover, Example Embodiment 2 provides, but is not limited to, the four kinds of suction ports (201, 203, 204, 205) in the scroll mechanism (200). Alternatively, two, three, or five or more suction ports may be provided.

[0183] In addition, in Example Embodiment 1, the pre-throttle valve (60) is provided at a part of the suction passage connected to the first suction port (55) of the expansion mechanism (50) and on the downstream side of the point branching apart from the suction passage connected to the second suction port (56), which is not a limitation. The pre-throttle valve (80) may be provided upstream of the branch point. In this case, the pre-throttle valve adjusts the total flow rate of the refrigerant to the first and second suction ports (55, 56).

INDUSTRIAL APPLICABILITY

[0184] As described above, the present invention is useful in refrigerating apparatuses including an expansion mechanism generating power by fluid expansion.

Claims

1. A refrigerating apparatus including an expansion mechanism (50, 100, 200) which includes a first member (71, 81, 102, 112, 210) and a second member (75, 85, 116, 124, 220), which are in eccentric and relative movement, and generates power by expansion of fluid in a fluid chamber (72, 82, 230) formed between the members, **characterized in that:**

a main suction hole (55, 103, 201) connecting the fluid chamber (72, 82, 230) to a suction passage (24) first in a suction stroke, and an auxiliary suction hole (56, 104, 113, 114, 203, 204,

205) connecting the fluid chambers (72, 82, 230) to a suction passage (27) after connection of the main suction hole (55, 103, 201) are formed in the expansion mechanism (50, 100, 200).

2. The apparatus of claim 1, wherein in the expansion mechanism (50, 100, 200), the fluid chamber (72, 82, 230) is defined so that at least a suction stroke and a discharge stroke are performed independently.
3. The apparatus of claim 1, wherein the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) is formed to open at a bottom of the fluid chamber (72, 230).
4. The apparatus of claim 1, wherein an on-off valve (61) is provided in the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205), and a check valve (95) allowing flow from the on-off valve (61) to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) is provided downstream of the on-off valve (61).
5. The apparatus of claim 1, comprising:
 - a bypass circuit (65) bypassing the expansion mechanism (50, 100, 200); and
 - a bypass flow rate adjusting valve (66) provided in the bypass circuit (65).
6. The apparatus of claim 5, further comprising:
 - a bypass flow rate control means (94) configured to control the bypass flow rate adjusting valve (66) on the basis of a pressure of the fluid introduced in the expansion mechanism (50, 100, 200).
7. The apparatus of claim 1, wherein a flow rate adjusting valve (60) is provided in the suction passage (24) connected to the main suction hole (55, 103, 201).
8. The apparatus of claim 7, wherein the flow rate adjusting valve (60) is provided downstream of a point branching apart from the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205).
9. The apparatus of claim 7, further comprising:
 - flow rate control means (92) configured to control the flow rate adjusting valve (60) on the basis of a pressure of the fluid introduced in the expansion mechanism (50, 100, 200).

10. The apparatus of claim 1, comprising:

on-off valve control means (93) configured to control an on-off valve (61) provided in the suction passage (27) connected to the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) on the basis of a pressure of the fluid introduced in the expansion mechanism (50, 100, 200).

11. The apparatus of claim 10, wherein

a plurality of auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) are provided in the expander, and on-off valves (61) are provided in the suction passages (27) connected to the auxiliary holes, and when the pressure is larger than a target value, the on-off valve control means (93) opens the on-off valves (61) sequentially so that the fluid chamber (72, 82, 230) is connected sequentially to the suction passages (27) through the auxiliary suction holes (56, 104, 113, 114, 203, 204, 205).

12. The apparatus of claim 10, wherein

the auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) includes a plurality of auxiliary suction holes connected to suction passages (27), and on-off valves (61) are provided in the suction passages (27), and when the pressure is smaller than a target value, the on-off valve control means (93) controls the on-off valves (61) to sequentially close the auxiliary suction holes (56, 104, 113, 114, 203, 204, 205) in reverse order of connection from one connected to the fluid chamber (72, 82, 230) last.

13. The apparatus of claim 11 or 12, further comprising:

bypass flow rate control means (94) for controlling a bypass flow rate adjusting valve (66) provided in the bypass circuit (65) bypassing the expansion mechanism (50, 100, 200),

wherein the bypass flow rate control means (94) controls the bypass flow rate adjusting valve (66) so that the pressure value is the target value, and the on-off valve control means (93) opens/closes the on-off valves (61) when the bypass flow rate adjusting valve (66) reaches a predetermined opening.

14. The apparatus of claim 13, further comprising:

flow rate control means (92) for controlling a flow rate adjusting valve (60) provided in the suction passage (24) connected to the main suction hole (55, 103, 201),

wherein the flow rate control means (92) controls the flow rate adjusting valve (60) to adjust a flow rate in the expansion mechanism (50, 100, 200) when the

pressure is smaller than the target value even when the bypass flow rate adjusting valve (66) and the on-off valve (61) are closed.

15. The apparatus of claim 1, wherein the expansion mechanism (50, 100) includes a plurality of rotary mechanism sections (70, 80, 101, 111, 121) connected to each other in series in an increasing order of displacement volume, and the main suction hole (55, 103) and the auxiliary suction hole (56, 104, 113, 114) are formed in a rotary mechanism section (70, 101, 111) precedent to a last rotary mechanism section (80, 121).

16. The apparatus of claim 15, wherein the expansion mechanism (50) includes two rotary mechanism sections (70, 80) connected to each other in series, and the main suction hole (55) and the auxiliary suction hole (56) are formed in a precedent rotary mechanism section (70) having a smaller displacement volume.

17. The apparatus of claim 15, wherein the auxiliary suction hole (56, 104, 113, 114) is formed at an angle point obtained by adding a predetermined compensation value to an angle point geometrically obtained based on a desired displacement volume.

18. The apparatus of claim 17, wherein the desired displacement volume is a displacement volume necessary in a cooling operation.

19. The apparatus of claim 1, wherein the expansion mechanism (200) includes a scroll mechanism including a pair of scroll members (210, 220) including end plates and scroll wraps standing on the end plates, the wraps (211, 221) of the scroll members (210, 220) being in engagement with each other to form at least a pair of fluid chambers (231, 232), and the main suction hole (201) and the auxiliary suction hole (203, 204, 205) are formed at points connected to the fluid chambers (231, 232) in a suction stroke of the scroll mechanism.

20. The apparatus of claim 1, wherein refrigerant of CO₂ is used as the fluid for performing a supercritical refrigeration cycle.

21. An expander including an expansion mechanism (50, 100, 200), which includes a first member (71, 81, 102, 112, 210) and a second member (75, 85, 116, 124, 220), which are in eccentric and relative movement, and generates power by expansion of fluid in a fluid chamber (72, 82, 230) formed between the members, wherein

a main suction hole (55, 103, 201) connecting the fluid chamber (72, 82, 230) to a suction passage (24) first in a suction stroke, and an auxiliary suction hole (56, 104, 113, 114, 203, 204, 205) connecting the fluid chamber (72, 82, 230) to a suction passage (27) 5 after connection of the main suction hole (55, 103, 201) are formed in the expansion mechanism (50, 100, 200).

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55

1

FIG. 1

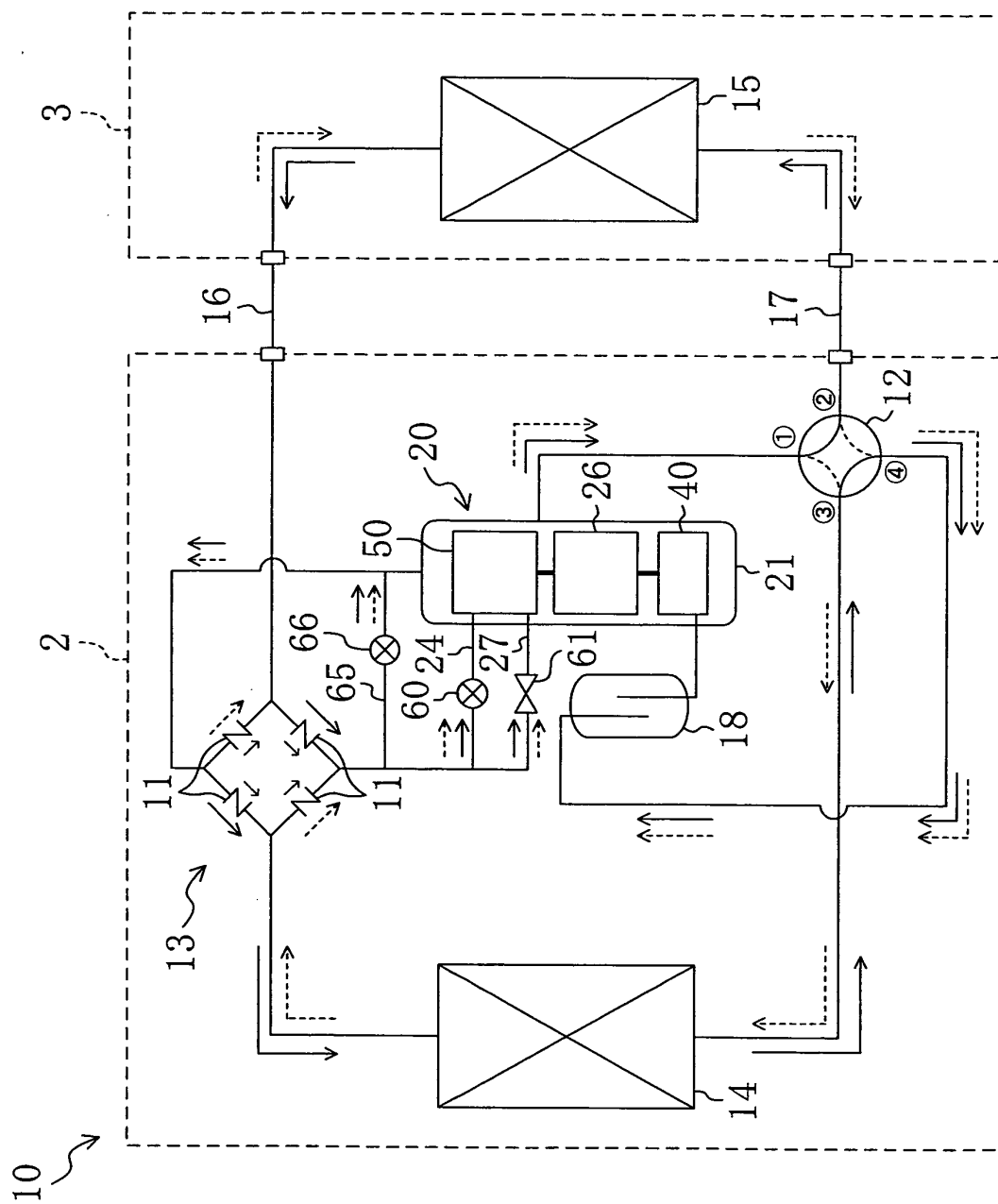


FIG. 2

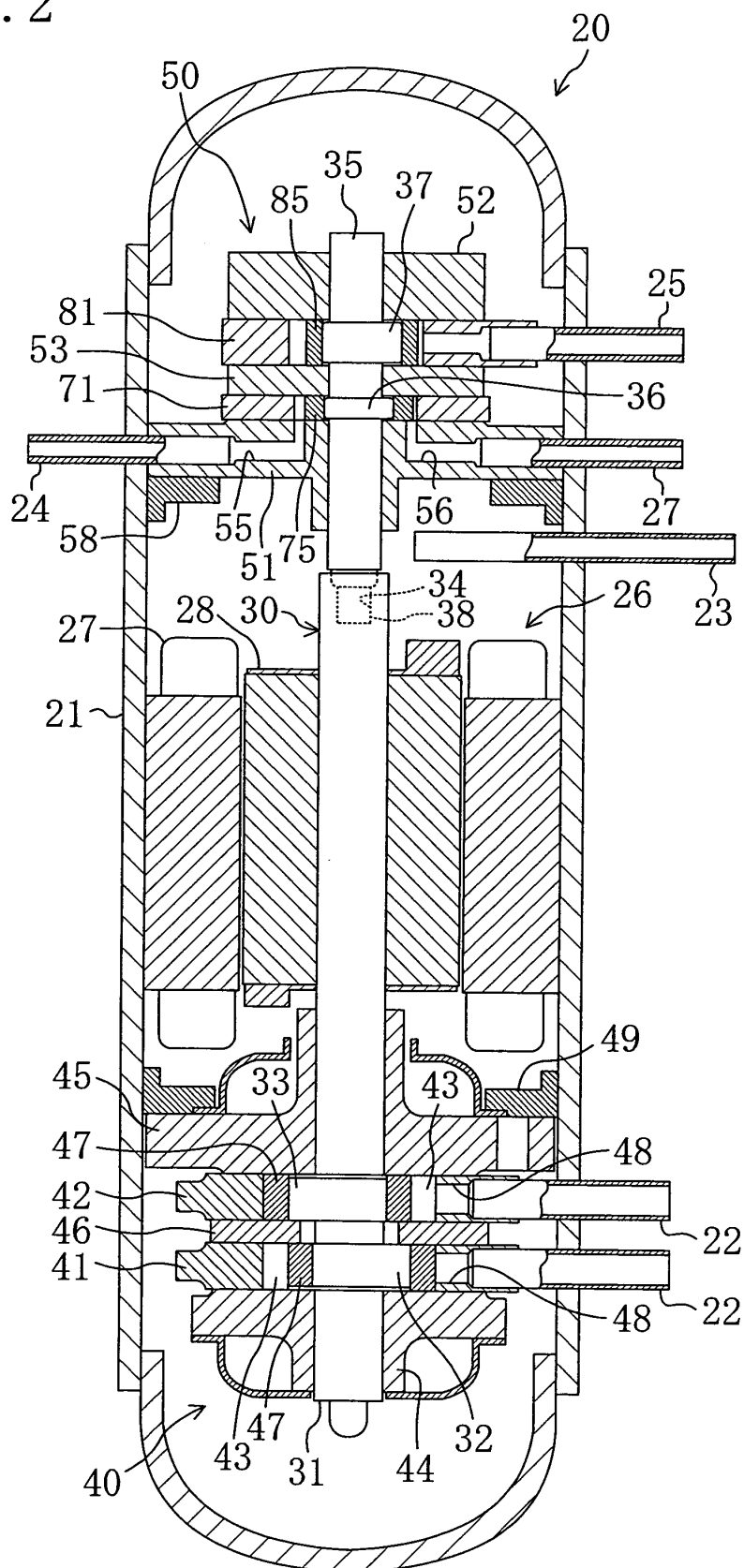


FIG. 3

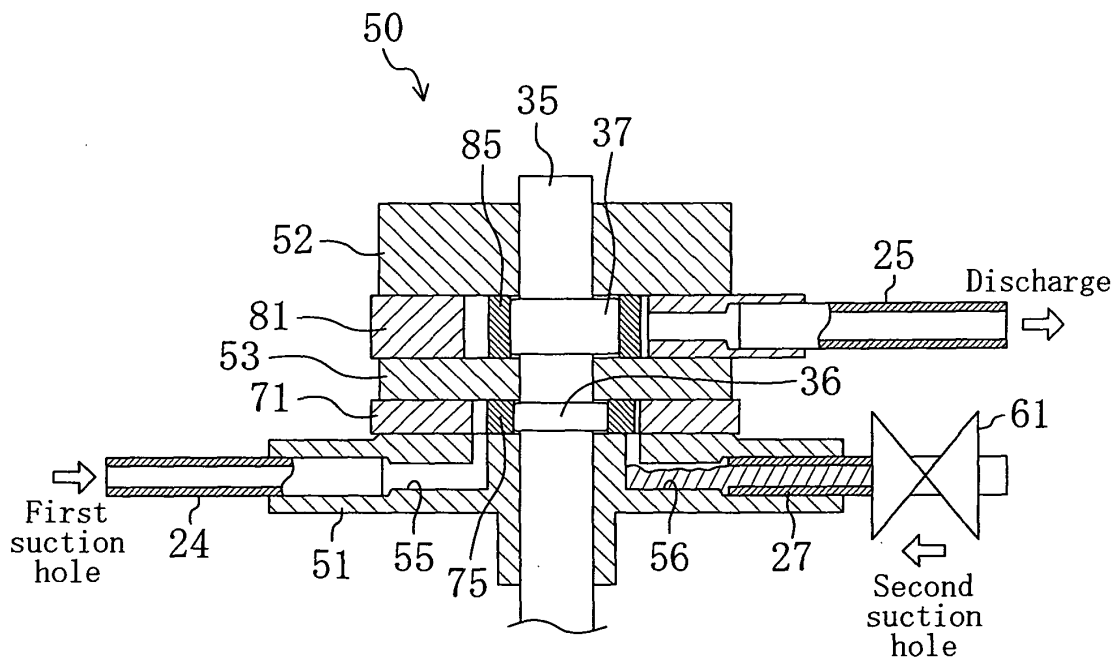


FIG. 4

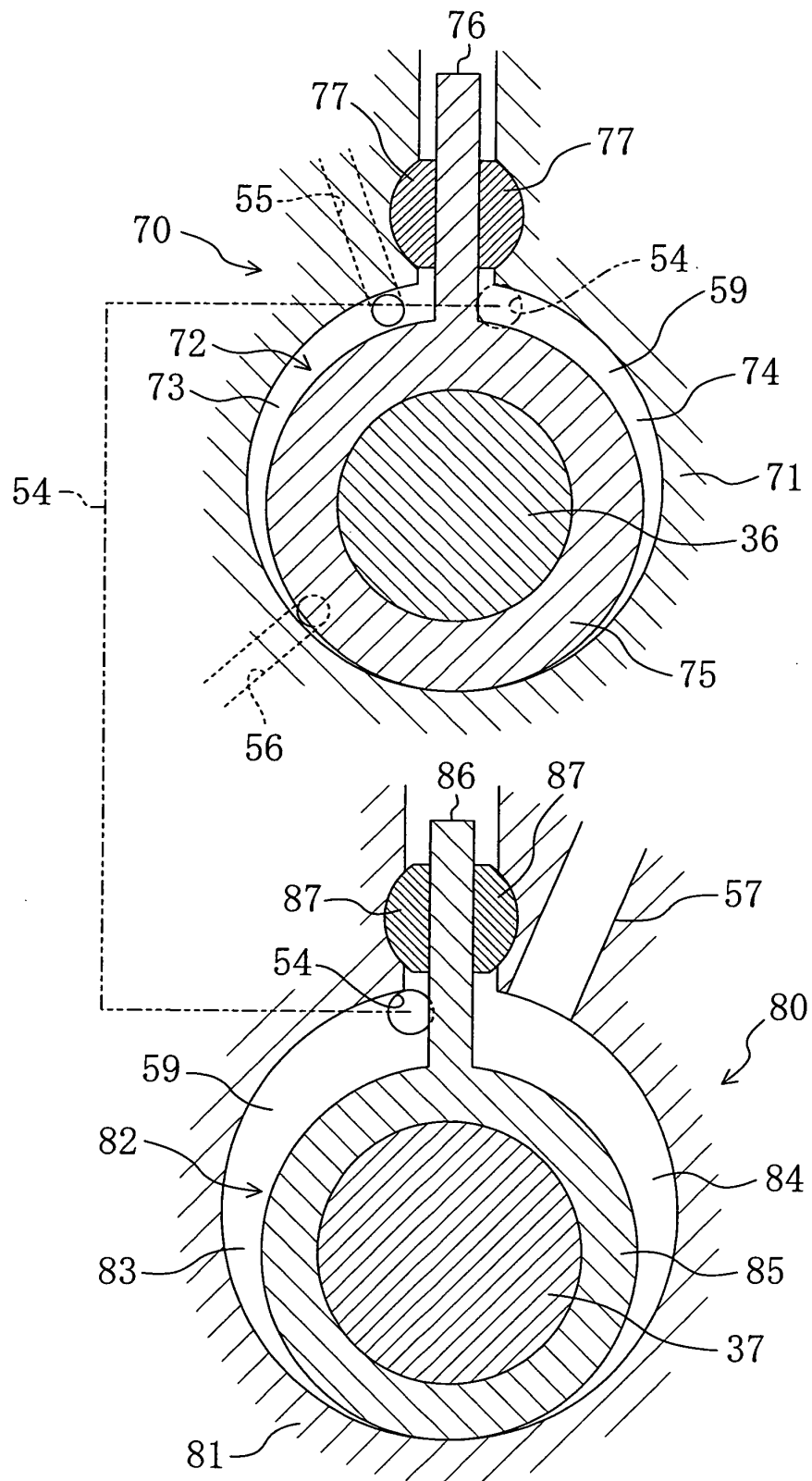


FIG. 5

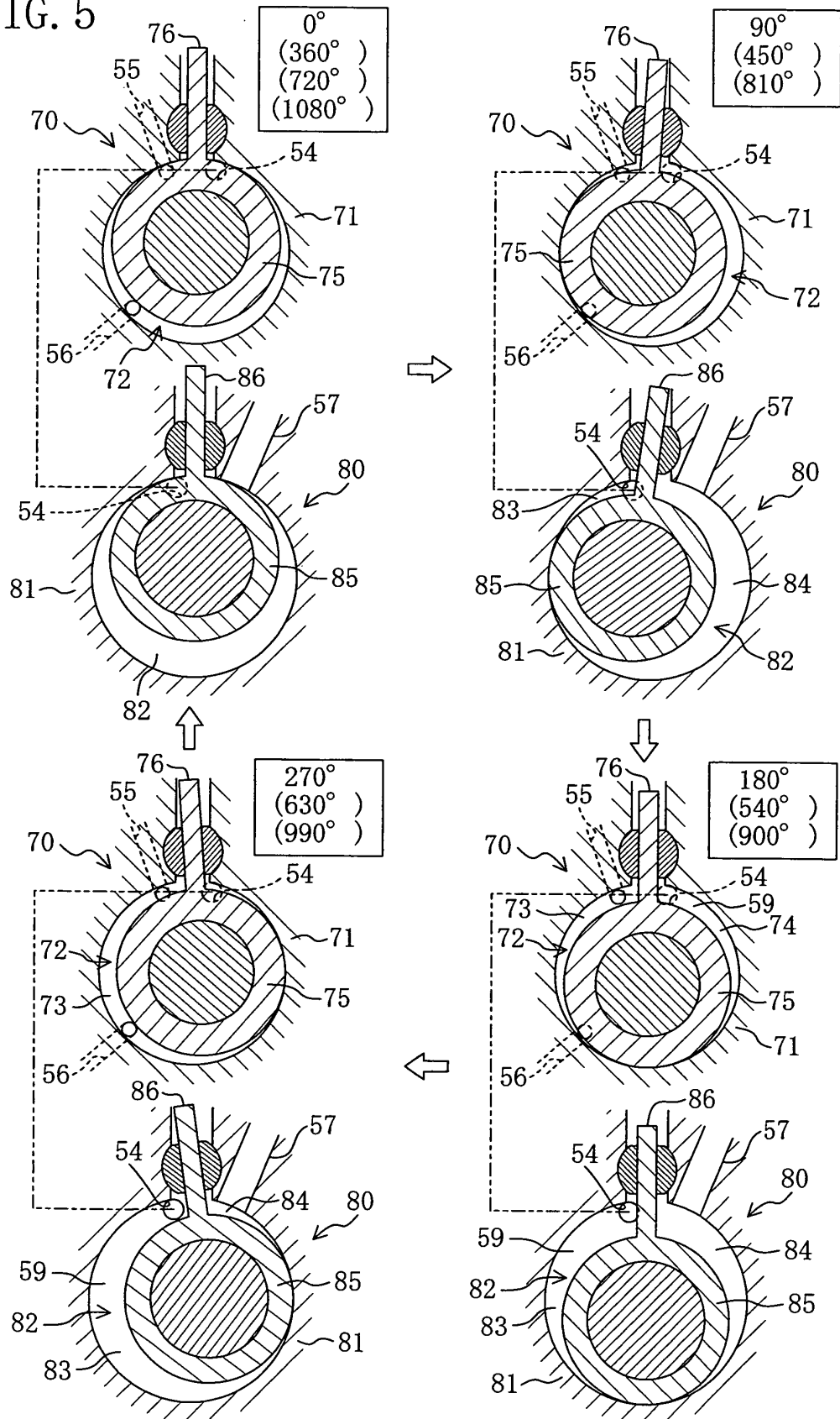


FIG. 6

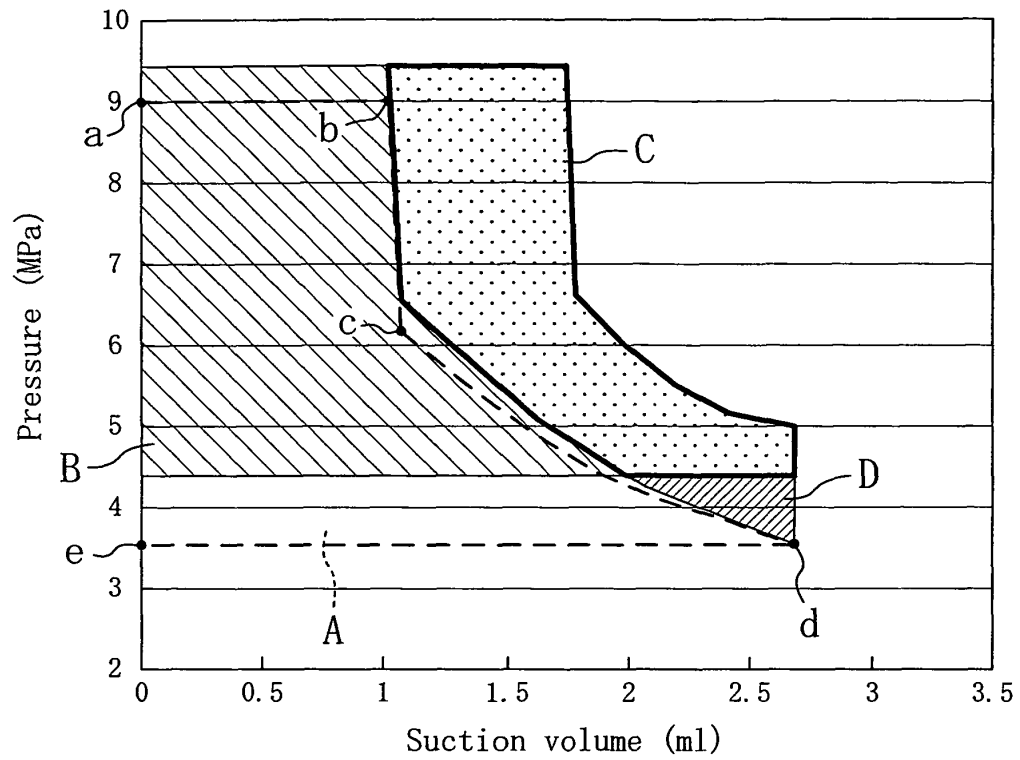


FIG. 7

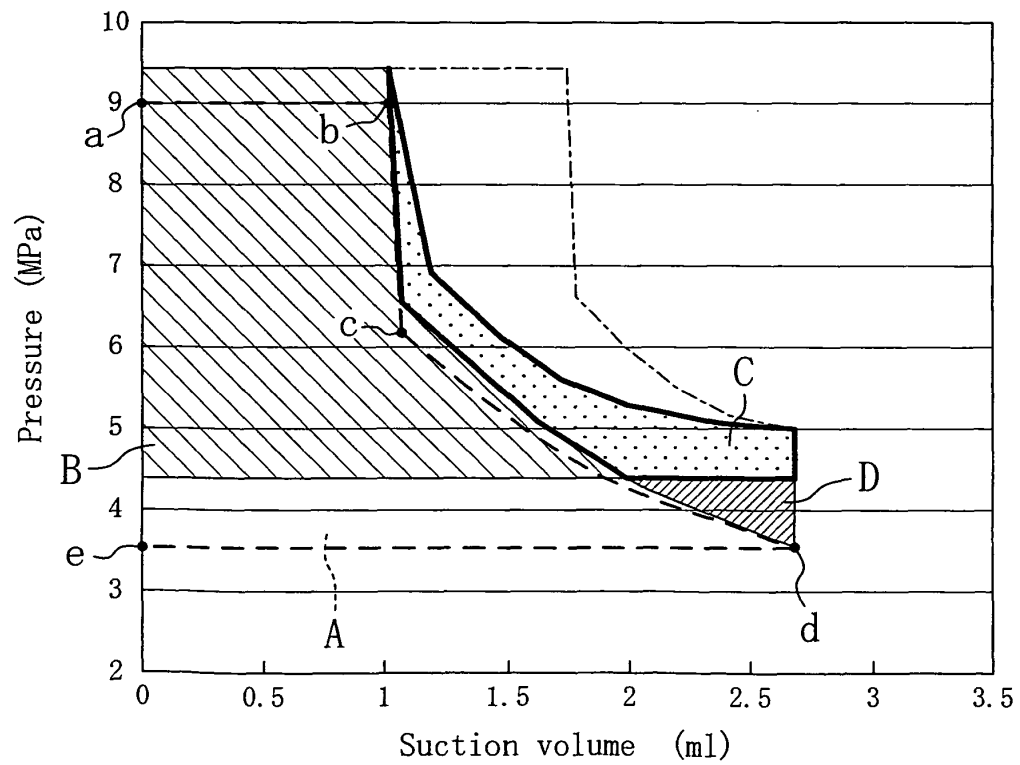


FIG. 8

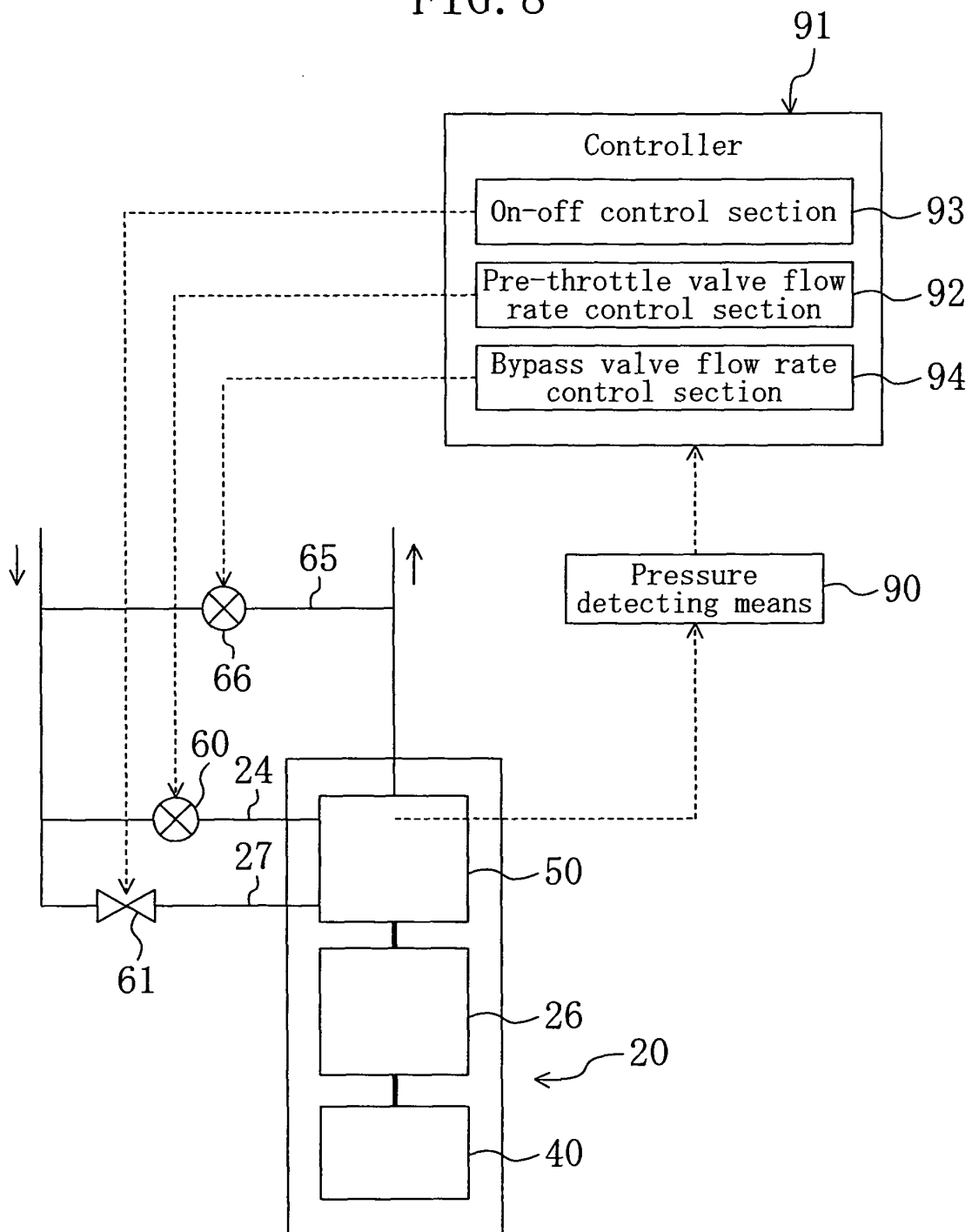


FIG. 9

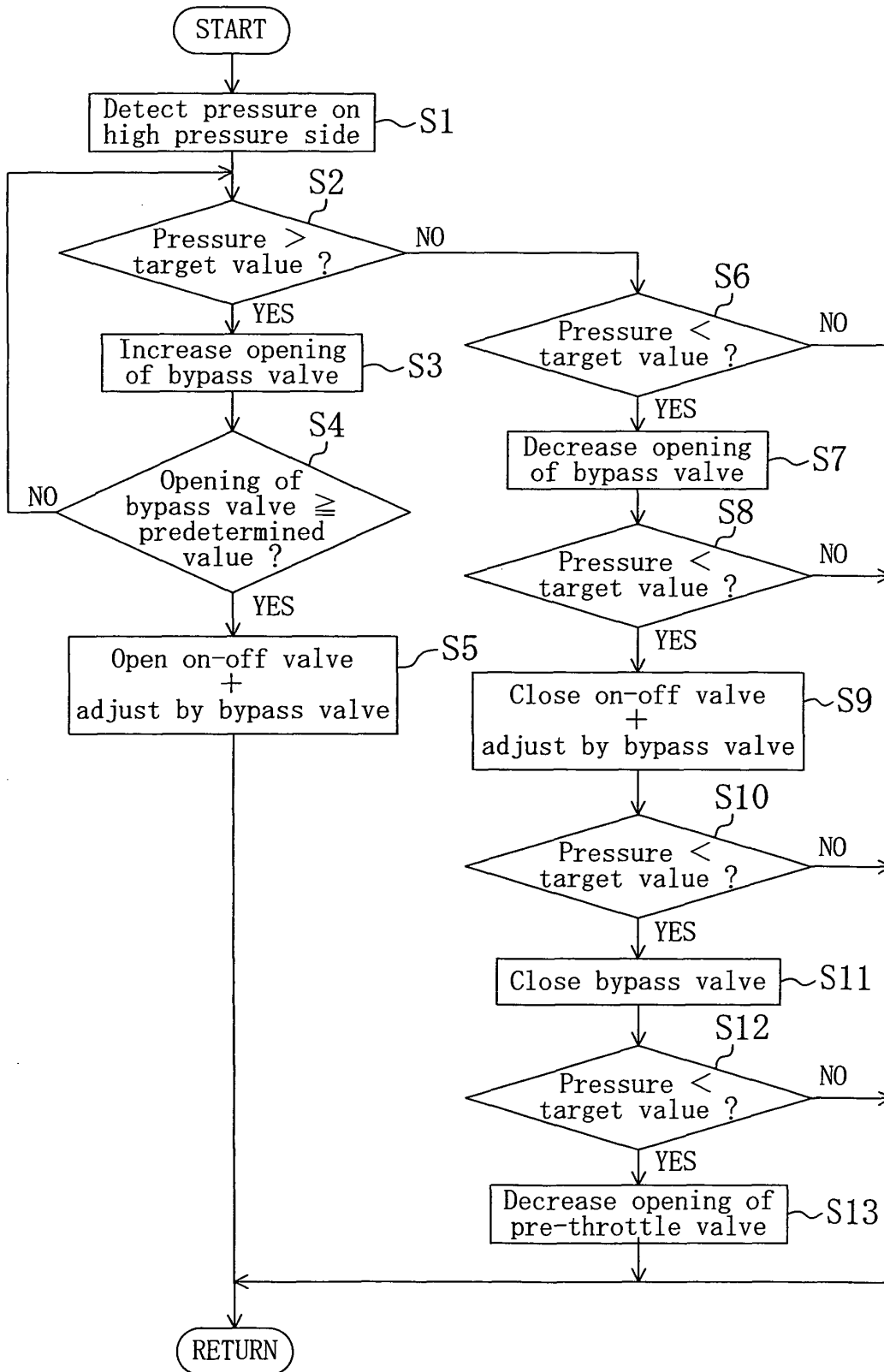


FIG. 10

Step	Opening (%)			
	Pre-throttle valve	Bypass valve	Second suction valve	Third suction valve
-3	40	Fully closed (0)	closed	closed
-2	60			
-1	80			
0	Fully opened (100)	20	Opened	Opened
1		40		
2		60		
3		80		
4		0		
5		20		
6		40		
7		60		
8		80		
9		0		
10		20		
11		40		
12		60		

Pressure > target value
↓

FIG. 11

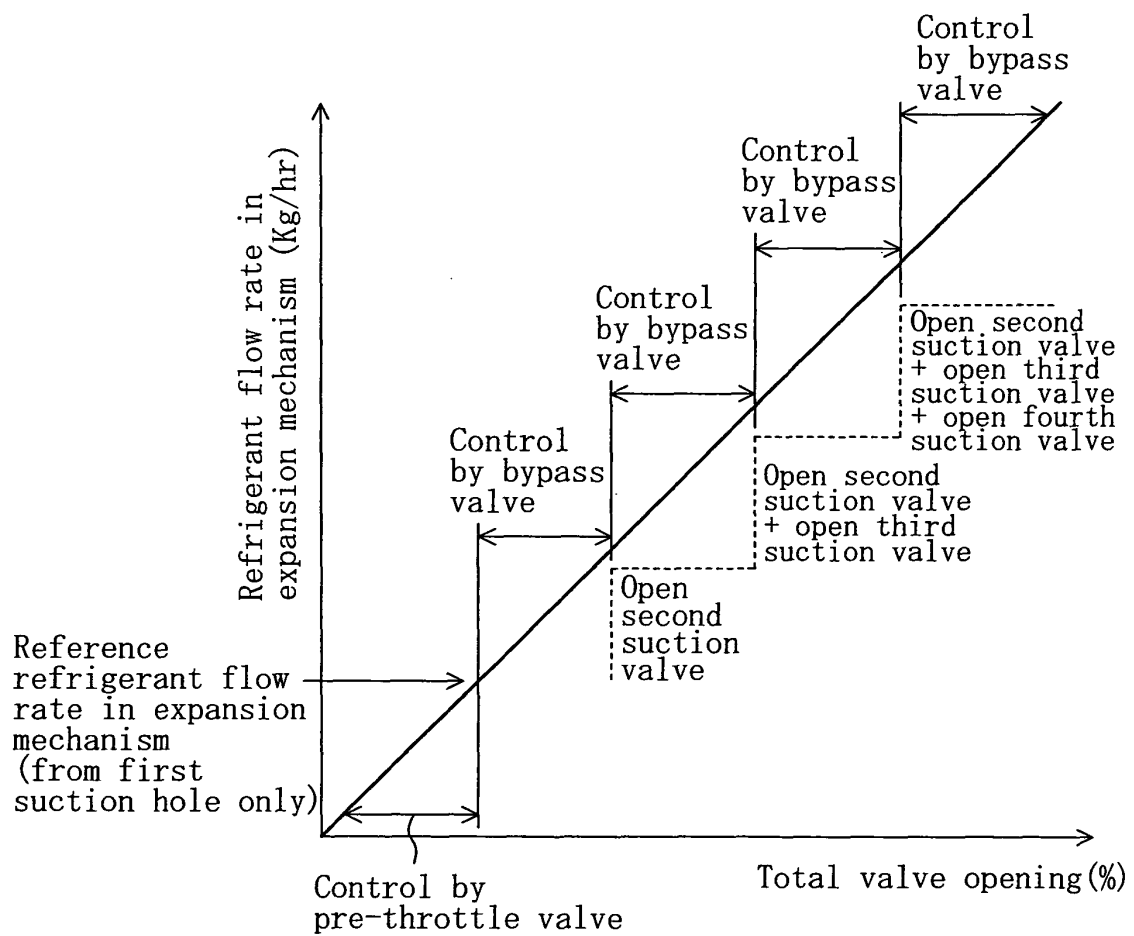


FIG. 12

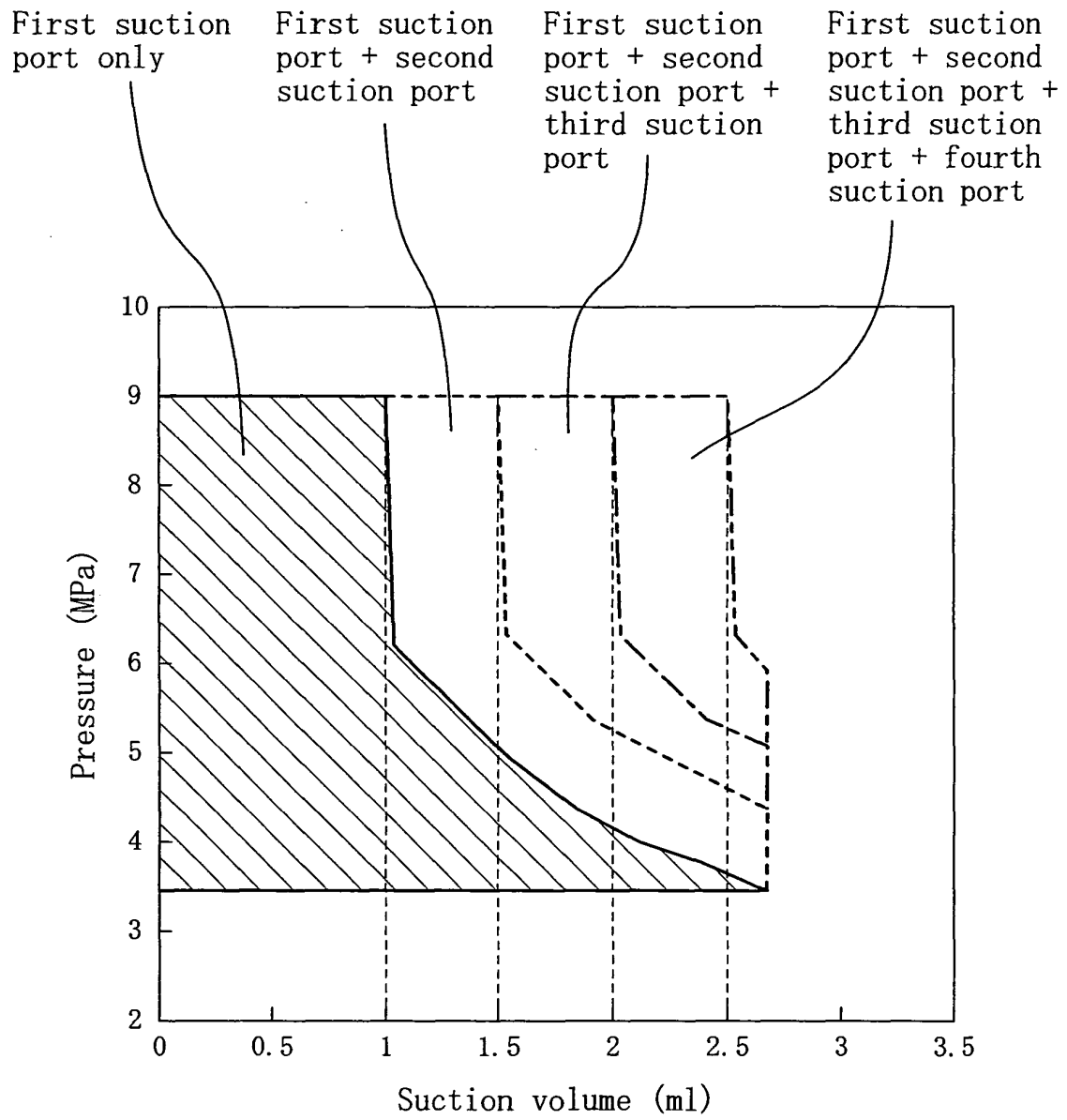


FIG. 13

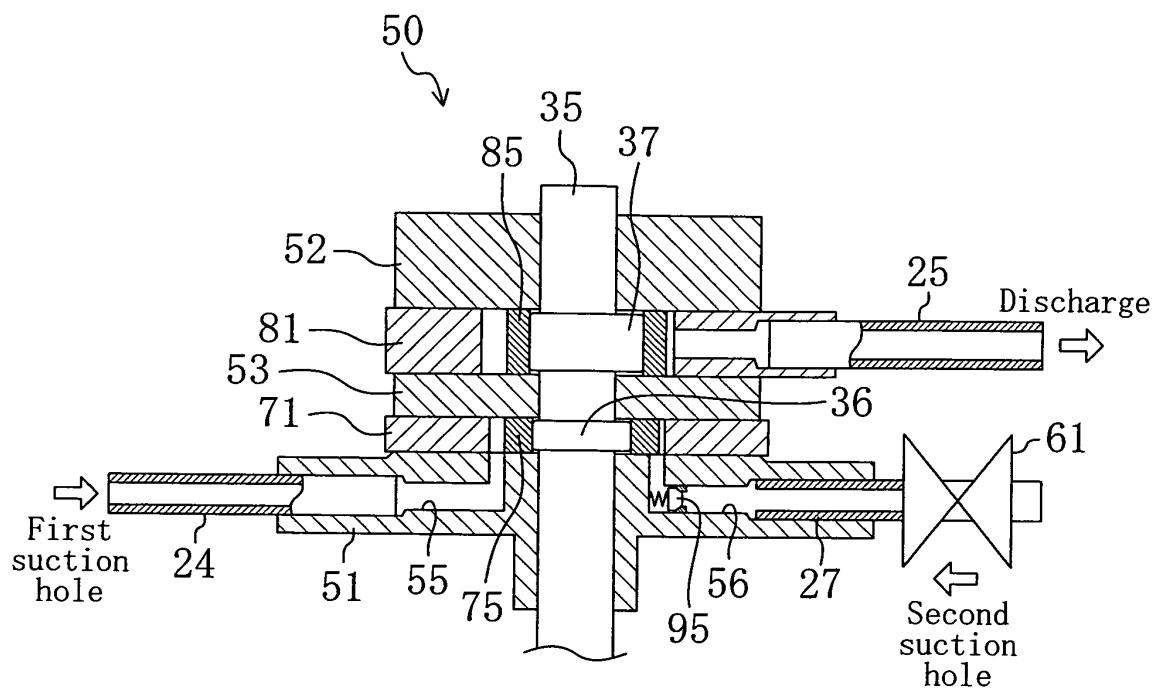
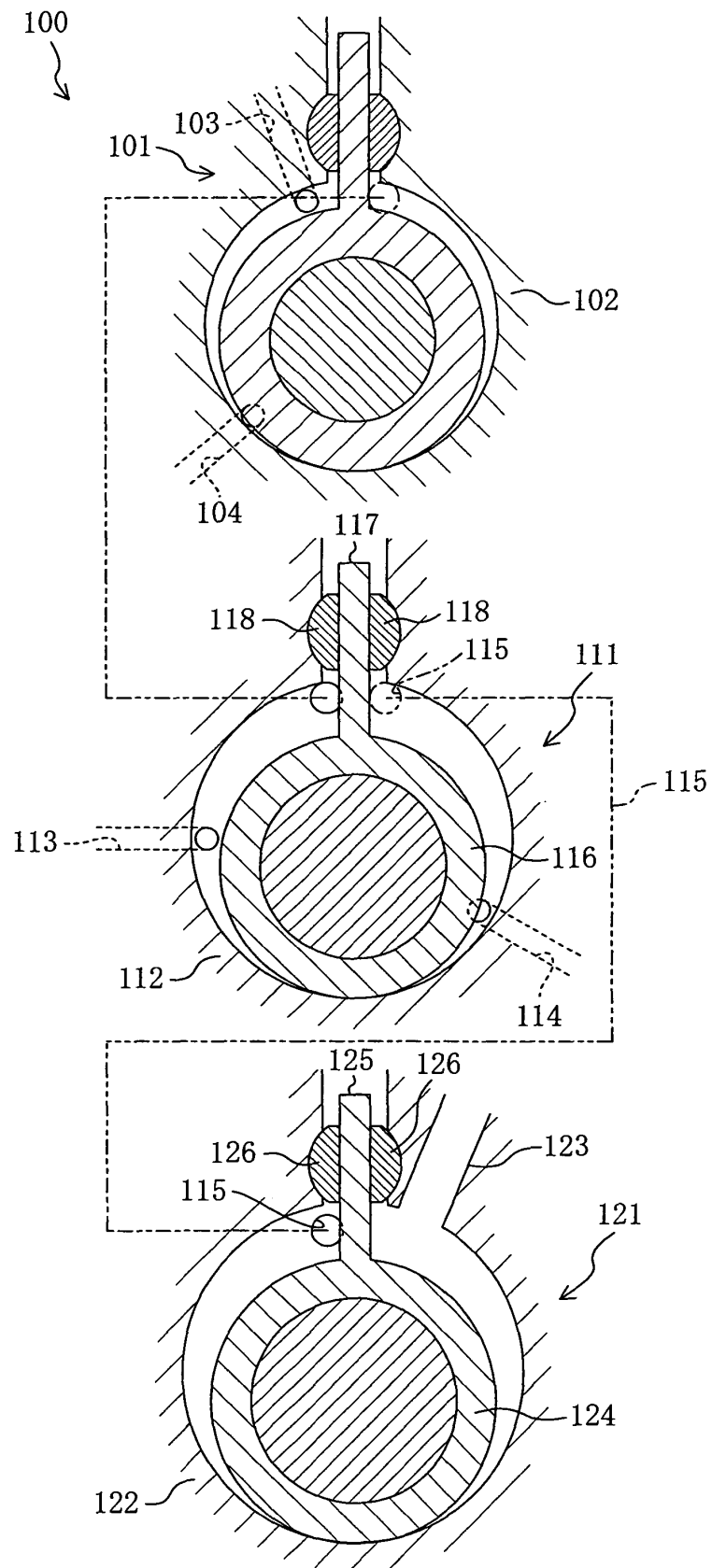


FIG. 14



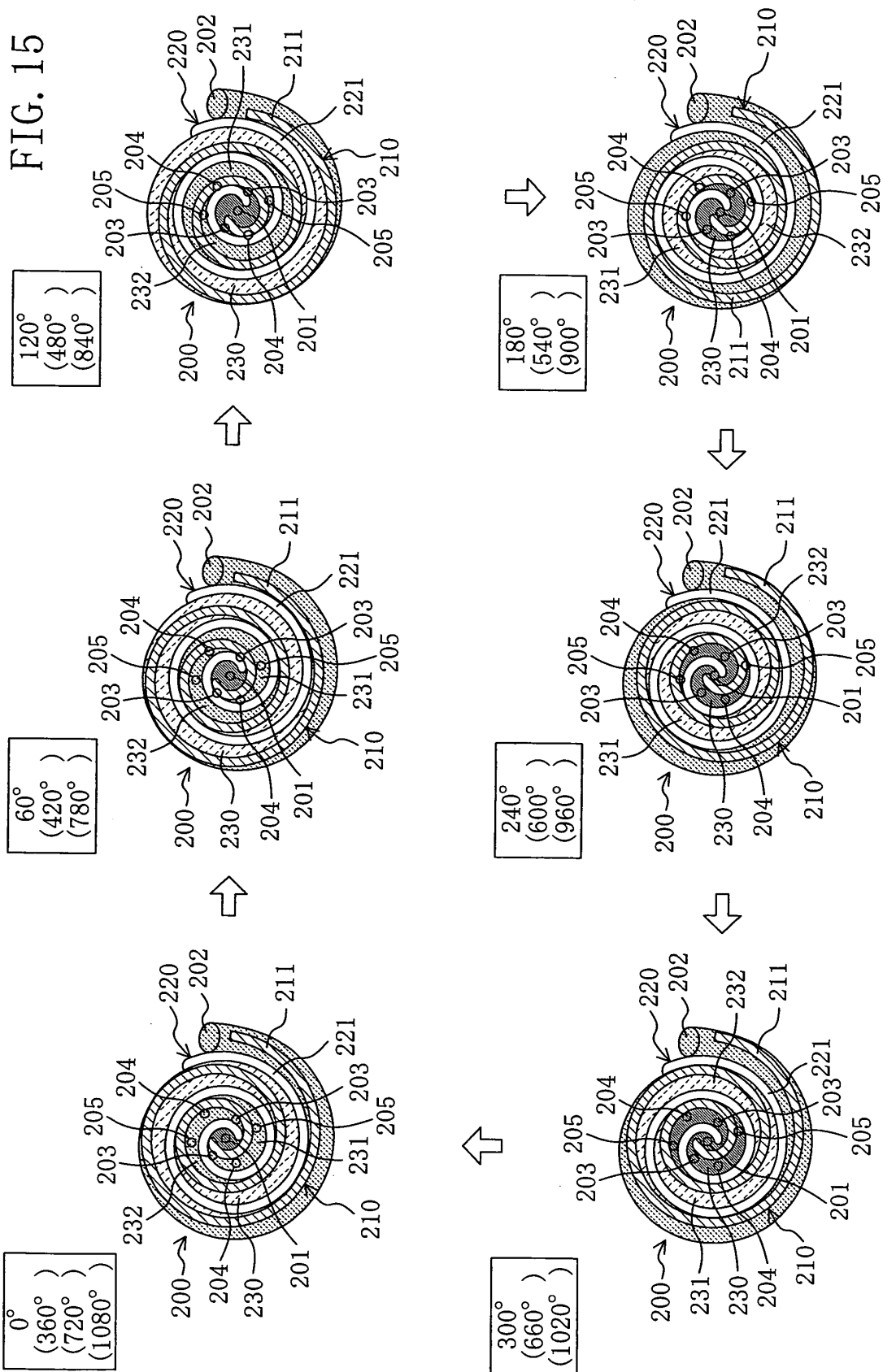


FIG. 16

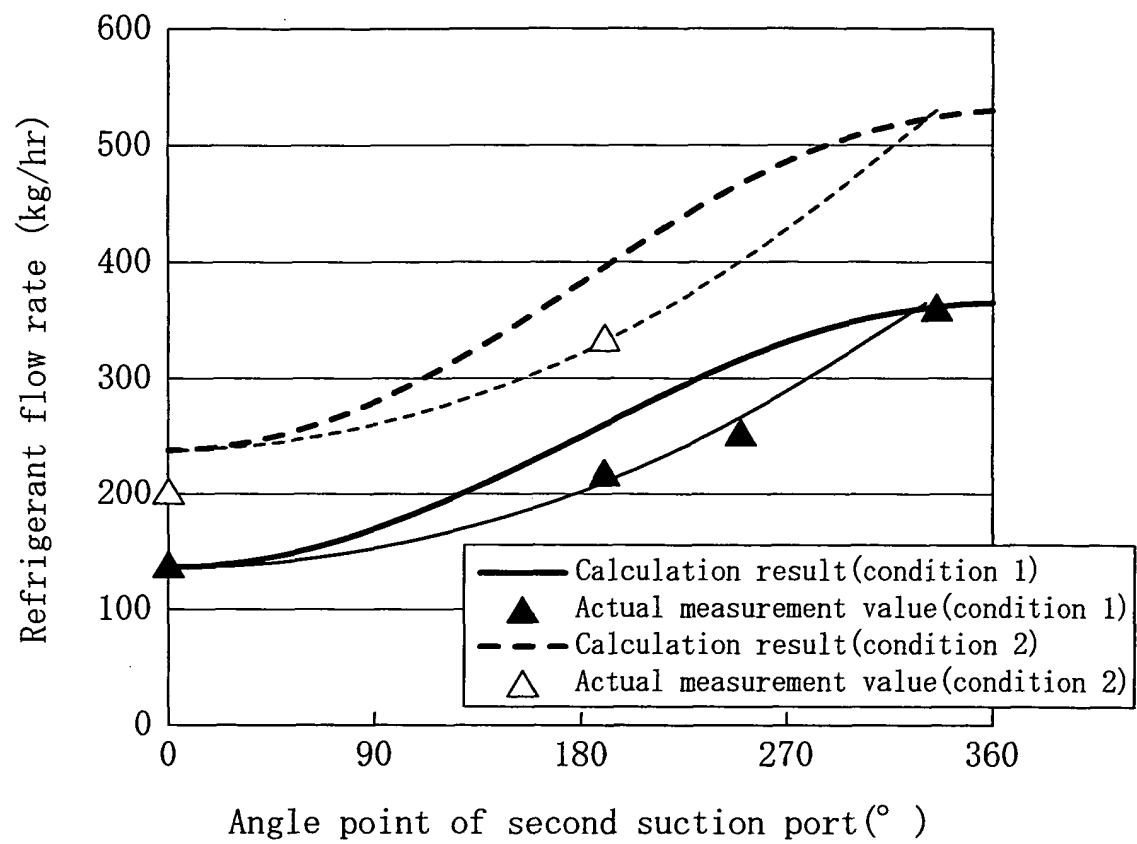


FIG. 17

		High pressure (kPa)	Temperature at gas cooler outlet (°C)	Low pressure (kPa)	Temperature on suction side of compressor (°C)	Expansion ratio	Displacement volume necessary in cooling operation	Result of geometric calculation	Designed angle point
Actual value in air conditioner	Heating	8500	25	3500	2.2	2.7	1.4	(114.7)	172.7
	Cooling	9500	36	4200	12.2				
Degrade performance of indoor heat exchanger	Heating	9000	26	3500	2.2	2.8	1.3	(100.4)	152.8
	Cooling	9500	36	4000	10.3				
Enhance performance of indoor heat exchanger	Heating	8000	24	3500	2.2	2.7	1.5	(134.8)	199.8
	Cooling	9500	36	4500	15.0				
Degrade performance of outdoor heat exchanger	Heating	8500	25	3300	0.0	3.0	1.6	(127.5)	190.2
	Cooling	10000	39	4200	12.2				

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/073703

A. CLASSIFICATION OF SUBJECT MATTER <i>F01C21/18</i> (2006.01) i, <i>F01C1/02</i> (2006.01) i, <i>F01C1/356</i> (2006.01) i, <i>F01C11/00</i> (2006.01) i, <i>F01C13/04</i> (2006.01) i, <i>F01C20/18</i> (2006.01) i, <i>F01C20/24</i> (2006.01) i, <i>F25B1/00</i> (2006.01) i, <i>F25B11/02</i> (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) <i>F01C21/18</i> , <i>F01C1/02</i> , <i>F01C1/356</i> , <i>F01C11/00</i> , <i>F01C13/04</i> , <i>F01C20/18</i> , <i>F01C20/24</i> , <i>F25B1/00</i> , <i>F25B11/02</i>		
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 1996-2008 Kokai Jitsuyo Shinan Koho 1971-2008 Toroku Jitsuyo Shinan Koho 1994-2008		
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 2004-197640 A (Daikin Industries, Ltd.), 15 July, 2004 (15.07.04), Full text; all drawings & WO 2004/055331 A1	1, 3, 5, 6, 10, 19-21 4, 7-9, 11, 12, 16-18
Y		
X	JP 2005-256667 A (Daikin Industries, Ltd.), 22 September, 2005 (22.09.05), Full text; all drawings & WO 2005/088077 A1 & EP 1724436 A1	1, 2, 5, 6, 10, 15, 20, 21 4, 7-9, 11, 12, 16-18
Y		
Y	JP 2004-150748 A (Matsushita Electric Industrial Co., Ltd.), 27 May, 2004 (27.05.04), Full text; all drawings & US 2004/0083751 A1 & EP 1416231 A1	7-9
☒ 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 29 February, 2008 (29.02.08)		Date of mailing of the international search report 11 March, 2008 (11.03.08)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/073703

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 2003-269103 A (Matsushita Electric Industrial Co., Ltd.), 25 September, 2003 (25.09.03), Par. Nos. [0033], [0036]; Figs. 1, 2, 4, 5 (Family: none)	11, 12
Y	JP 2006-46222 A (Daikin Industries, Ltd.), 16 February, 2006 (16.02.06), Full text; all drawings & WO 2006/013959 A1 & EP 1790818 A1	4
A	JP 2001-116371 A (Daikin Industries, Ltd.), 27 April, 2001 (27.04.01), Full text; all drawings (Family: none)	5, 6, 13, 14
A	JP 2000-227080 A (Nippon Soken, Inc.), 15 August, 2000 (15.08.00), Full text; all drawings (Family: none)	1-21
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 92218/1986 (Laid-open No. 203901/1987) (Kobe Steel, Ltd.), 26 December, 1987 (26.12.87), Full text; all drawings (Family: none)	1-21
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 5126/1985 (Laid-open No. 122301/1986) (Nissan Motor Co., Ltd.), 01 August, 1986 (01.08.86), Full text; all drawings (Family: none)	1-21

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2007/073703

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 matter common to the inventions of claims 1 - 21 is an expander having an auxiliary inlet hole, as described in claims 1 and 21. However, the search has revealed that this matter is not novel, since it was disclosed in both JP 2004-197640 A (Daikin Industries, Ltd.), 15 July, 2004 (15.07.04), the full descriptions and all the figures, and JP 2005-256667 A (Daikin Industries, Ltd.), 22 September, 2005 (22.09.05), the whole specification and all the drawings. As a result, this common matter (i.e., the expander having the auxiliary inlet hole) is not the special technical feature within the meaning of PCT Rule 13.2, second sentence, since the common matter (i.e., the expander having the auxiliary inlet hole) (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.:

Remark on Protest
the

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, 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.

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

does not explicitly specify any contribution over the prior art. Consequently, no common matter can be found as common to claims 1 - 21.

Hence, it is apparent that the inventions of claims 1 - 21 do not comply with the requirement of unity of invention.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2004150748 A [0004]
- JP 2001116371 A [0004]