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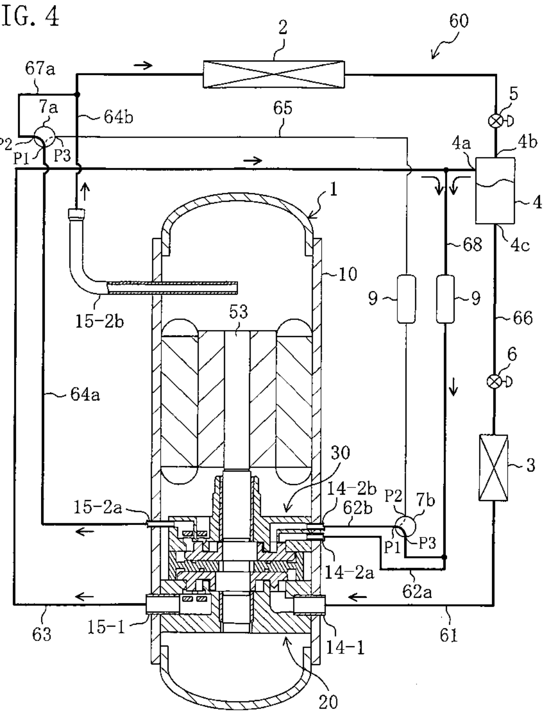
(54) **REFRIGERATING APPARATUS**

(57) In order to adjust a volume ratio of a compressor (1) in which a plurality of compression mechanisms (20, 30) are mechanically connected together through a single drive shaft (53), in a refrigerating apparatus in which a two-stage compression refrigeration cycle is performed, the compression mechanisms (20, 30) include four cylinder chambers (C1, C2, C3, C4), and switching valves (7a, 7b) are provided, which are configured to change a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism.

FIG. 4



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Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigerating apparatus for a two-stage compression refrigeration cycle, and particularly relates to a technique for adjusting a suction volume ratio in a compressor in which a plurality of compression mechanisms are mechanically connected together through a single drive shaft.

BACKGROUND ART

[0002] Conventionally, a refrigerating apparatus has been known, in which a two-stage compression refrigeration cycle is performed. In such a refrigerating apparatus, e.g., a compressor is used, in which two compression mechanisms are mechanically connected to a single drive shaft (see, e.g., Patent Document 1). In the compressor of the refrigerating apparatus, one of the compression mechanisms serves as a low-pressure compression mechanism, and the other compression mechanism serves as a high-pressure compression mechanism.

CITATION LIST

PATENT DOCUMENT

[0003] PATENT DOCUMENT 1: Japanese Patent Publication No. 2007-023993

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0004] In, e.g., a refrigeration cycle in which carbon dioxide is used as refrigerant, there is a problem that efficiency degradation due to a heat loss is increased, and it is less likely to obtain high COP. Thus, it is possible that, as described above, a compression is performed at multiple stages to increase the COP. In such a case, an intermediate pressure is changed depending on a volume ratio of the low-pressure compression mechanism to the high-pressure compression mechanism. However, a change in intermediate pressure results in a change in COP, and therefore it is desired that the intermediate pressure is controlled to an optimum level.

[0005] If there are two compressors, i.e., a low-pressure compressor and a high-pressure compressor, a rotational speed of each of the compressors is changed to change a quantitative ratio (volume ratio) of refrigerant to be taken into the compressor, thereby controlling the COP. However, in the compressor in which the two compression mechanisms are connected to the single drive shaft as described in Patent Document 1, rotational speeds of the low-pressure and high-pressure compression mechanisms are equal to each other, and a suction volume ratio of the low-pressure compression mechanism to the high-pressure compression mechanism is constant. Thus, the intermediate pressure cannot be controlled. The same applies not only to a case where refrigerant is carbon dioxide, but also to a case where other type of refrigerant is used.

[0006] The present invention has been made in view of the foregoing problem, and it is an objective of the present invention to, in a refrigerating apparatus in which a two-stage compression refrigeration cycle is performed, adjust a suction volume ratio in a compressor in which a plurality of compression mechanisms are mechanically connected together through a single drive shaft, and allow an operation with optimum COP.

SOLUTION TO THE PROBLEM

[0007] A first aspect of the invention is intended for a refrigerating apparatus in which a two-stage compression refrigeration cycle is performed, which includes a refrigerant circuit (60), (180) connected to a compressor (1), (100) in which a plurality of compression mechanisms (20, 30), (110, 120, 130, 140) are mechanically connected together through a single drive shaft (53), (173).

[0008] The refrigerating apparatus further includes four cylinder chambers (C1, C2, C3, C4) in the compression mechanisms (20, 30), (110, 120, 130, 140); and volume ratio changing units (7, 8), (107, 108) configured to change a ratio of a suction volume of a low-pressure compression mechanism to a suction volume of a high-pressure compression mechanism.

[0009] In the first aspect of the invention, in the refrigerating apparatus including the four cylinder chambers (C1, C2, C3, C4) in the compression mechanisms (20, 30), (110, 120, 130, 140), the volume ratio changing units (7, 8), (107, 108) change the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism while performing an operation.

[0010] A second aspect of the invention is intended for the refrigerating apparatus of the first aspect of the invention, in which the volume ratio changing unit (7, 8), (107, 108) is configured to change the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism (in some cases, hereinafter referred to as a "suction volume ratio" or merely referred to as a "volume ratio") by changing a combination of the four cylinder chambers (C1, C2, C3, C4).

[0011] In the second aspect of the invention, e.g., the combination of the cylinder chambers to be used as the low-pressure compression mechanism and the cylinder chambers to be used as the high-pressure compression mechanism is changed while performing the operation. That is, when two cylinder chambers are used for each of the low-pressure and high-pressure compression mechanisms, a combination of the low-pressure cylinder chambers and the high-pressure cylinder chambers is changed, and therefore the volume ratio can be adjusted depending on operational conditions when cylinder volumes of the compression chambers are different from each other. The volume ratio can be also adjusted depending on the operational conditions by using three cylinder chambers at the low-pressure stage and one cylinder chamber at the high-pressure stage, or by using one cylinder chamber at the low-pressure stage and three cylinder chambers at the high-pressure stage.

[0012] A third aspect of the invention is intended for the refrigerating apparatus of the first or second aspect of the invention, in which the plurality of compression mechanisms (20, 30) are a first compression mechanism (20) and a second compression mechanism (30), each of which includes two cylinder chambers (C1, C2), (C3, C4), each of the compression mechanisms (20, 30) includes a cylinder (21, 31) with a circular cylinder space and a circular eccentric piston (22, 32) eccentrically rotating in the cylinder space, an inner cylinder chamber (C2, C4) is formed on an inner circumferential side of the circular eccentric piston (22, 32) in the cylinder space, and an outer cylinder chamber (C1, C3) is formed on an outer circumferential side of the circular eccentric piston (22, 32).

[0013] In the third aspect of the invention, each of the two compression mechanisms (20, 30) provided in the compressor (1) includes the two cylinder chambers (C1, C2), (C3, C4) on the outer and inner circumferential sides of the circular pistons (22, 32). In the compressor (1) including the compression mechanisms (20, 30) having the inner cylinder chambers (C2, C4) on the inner circumferential side of the circular pistons (22, 32) and the outer cylinder chambers (C1, C3) on the outer circumferential side of the circular pistons (22, 32), the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism is changed while performing the operation.

[0014] A fourth aspect of the invention is intended for the refrigerating apparatus of the third aspect of the invention, in which the four cylinder chambers (C1, C2, C3, C4) are set to at least two suction volume levels.

[0015] In the fourth aspect of the invention, in the compressor using the compression mechanisms of the third aspect of the invention, in which the inner cylinder chambers (C2, C4) on the inner circumferential side of the circular pistons (22, 32) and the outer cylinder chambers (C1, C3) on the outer circumferential side of the circular pistons (22, 32) have volumes different from each other, the two compression mechanisms (20, 30) are configured so that the inner cylinder chambers (C2, C4) have the same volume, and the outer cylinder chambers (C1, C3) have the same volume. Thus, the compression mechanisms (20, 30) can be easily realized, which include the four cylinder chambers (C1, C2, C3, C4) set to at least two suction volume levels.

[0016] A fifth aspect of the invention is intended for the refrigerating apparatus of the third aspect of the invention, in which suction volumes of the four cylinder chambers (C1, C2, C3, C4) are different from each other.

[0017] In the fifth aspect of the invention, the volumes of the four cylinder chambers (C1, C2, C3, C4) are different from each other, and therefore the number of combination patterns of the cylinder chambers (C1, C2, C3, C4) for changing the volume ratio can be maximum. Thus, the present invention is available under various operational conditions.

[0018] A sixth aspect of the invention is intended for the refrigerating apparatus of any one of the third to fifth aspects of the invention, in which, when the first compression mechanism (20) is at the low-pressure stage and the second compression mechanism (30) is at the high-pressure stage, the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected together in parallel, and a state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected together in series.

[0019] In the sixth aspect of the invention, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, it is switched between the state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected in parallel and the state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected in series. Thus, the volume ratio can be adjusted between two operational states.

[0020] A seventh aspect of the invention is intended for the refrigerating apparatus of any one of the third to fifth aspects of the invention, in which the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) and one of the cylinder chambers (C4) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C3) of the second compression mechanism (30) is used as the high-pressure compression mechanism.

[0021] In the seventh aspect of the invention, it is switched between the state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and the state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) and one of the cylinder chambers (C4) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C3) of the second compression mechanism (30) is used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states.

[0022] An eighth aspect of the invention is intended for the refrigerating apparatus of any one of the third to fifth aspects of the invention, in which the volume ratio changing unit (8) is a switching mechanism which is switchable between a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and a state in which one of the cylinder chambers (C1) of the first compression mechanism (20) and one of the cylinder chambers (C3) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C2) of the first compression mechanism (20) and the other cylinder chamber (C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism.

[0023] In the eighth aspect of the invention, it is switched between the state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and the state in which one of the cylinder chambers (C1) of the first compression mechanism (20) and one of the cylinder chambers (C3) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C2) of the first compression mechanism (20) and the other cylinder chamber (C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states.

[0024] A ninth aspect of the invention is intended for the refrigerating apparatus of any one of the third to fifth aspects of the invention, in which, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which refrigerant is compressed in both of the cylinder chambers (C3, C4) of the second compression mechanism (30) to provide a difference between a suction pressure and a discharge pressure, and a state in which refrigerant is compressed in one of the cylinder chambers (C3), (C4) of the second compression mechanism (30) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other cylinder chamber (C4), (C3) allow uncompressed refrigerant to pass through the other cylinder chamber (C4), (C3) (a state in which inlet and outlet sides are communicated with each other in the other cylinder chamber).

[0025] In the ninth aspect of the invention, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, it is switched between the state in which refrigerant is compressed in both of the cylinder chambers (C3, C4) of the second compression mechanism (30), and the state in which refrigerant is compressed only in one of the cylinder chambers (C3), (C4) of the second compression mechanism (30), and uncompressed refrigerant passes through the other cylinder chamber (C4), (C3). Thus, the volume ratio can be adjusted between the two operational states.

[0026] A tenth aspect of the invention is intended for the refrigerating apparatus of any one of the third to fifth aspects of the invention, in which, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which refrigerant is compressed in both of the cylinder chambers (C1, C2) of the first compression mechanism (20) to provide a difference between a suction pressure and a discharge pressure, and a state in which refrigerant is compressed in one of the cylinder chambers (C1), (C2) of the first compression mechanism (20) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other cylinder chamber (C2), (C1) allow uncompressed refrigerant to pass through the other cylinder chamber (C2), (C1).

[0027] In the tenth aspect of the invention, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, it is switched between the state in which refrigerant is compressed in both of the cylinder chambers (C1, C2) of the first compression mechanism (20), and the state in which refrigerant is compressed only in one of the cylinder chambers (C1) of the first compression mechanism (20), and uncompressed refrigerant passes through the other cylinder chamber. Thus, the volume ratio can be adjusted between the two operational states.

[0028] An eleventh aspect of the invention is intended for the refrigerating apparatus of any one of the first to tenth aspects of the invention, in which the switching mechanism (7, 8) is a switching valve configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (20, 30).

[0029] In the eleventh aspect of the invention, the flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant is switched by the switching valve

(7, 8), thereby adjusting the volume ratio of the compressor (1) depending on the different operational states.

[0030] A twelfth aspect of the invention is intended for the refrigerating apparatus of any one of the first to eleventh aspects of the invention, in which the volume ratio changing unit (7, 8) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

[0031] In the twelfth aspect of the invention, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism is adjusted depending on the change in operational conditions.

[0032] A thirteenth aspect of the invention is intended for the refrigerating apparatus of the first or second aspect of the invention, in which the plurality of compression mechanisms (110, 120, 130, 140) are a first compression mechanism (110), a second compression mechanism (120), a third compression mechanism (130), and a fourth compression mechanism (140), each of which includes a single cylinder chamber, and each of the compression mechanisms (110, 120, 130, 140) includes a cylinder (111, 121, 131, 141) with a circular cylinder space and an eccentric piston (112, 122, 132, 142) eccentrically rotating in the cylinder space.

[0033] In the thirteenth aspect of the invention, each of the four compression mechanisms (110, 120, 130, 140) provided in the compressor (1) includes the cylinder (111, 121, 131, 141) with the circular cylinder space, and the eccentric piston (112, 122, 132, 142) eccentrically rotating in the cylinder space. In the compressor including the compression mechanisms (110, 120, 130, 140) in which the eccentric pistons (112, 122, 132, 142) eccentrically rotate in the cylinder spaces, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism is changed while performing the operation.

[0034] A fourteenth aspect of the invention is intended for the refrigerating apparatus of the thirteenth aspect of the invention, in which the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and a state in which the first compression mechanism (110), the second compression mechanism (120), and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the fourth compression mechanism (140) is used as the high-pressure compression mechanism.

[0035] In the fourteenth aspect of the invention, it is switched between the state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and the state in which the first compression mechanism (110), the second compression mechanism (120), and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the fourth compression mechanism (140) is used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states.

[0036] A fifteenth aspect of the invention is intended for the refrigerating apparatus of the thirteenth aspect of the invention, in which the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and a state in which the first compression mechanism (110) is used as the low-pressure compression mechanism, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are used as the high-pressure compression mechanism.

[0037] In the fifteenth aspect of the invention, it is switched between the state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and the state in which the first compression mechanism (110) is used as the low-pressure compression mechanism, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states.

[0038] A sixteenth aspect of the invention is intended for the refrigerating apparatus of the thirteenth aspect of the invention, in which a cylinder volume of at least one of the compression mechanisms is different from cylinder volumes of the other compression mechanisms, and the volume ratio changing unit (108) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and a state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism.

[0039] In the sixteenth aspect of the invention, in the configuration in which the cylinder volume of at least one of the compression mechanisms is different from the cylinder volumes of the other compression mechanisms, it is switched between the state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and the state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states.

[0040] A seventeenth aspect of the invention is intended for the refrigerating apparatus of the thirteenth aspect of the invention, in which, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which refrigerant is compressed in both of the third compression mechanism (130) and the fourth compression mechanism (140) to provide a difference between a suction pressure and a discharge pressure, and a state in which refrigerant is compressed in one of the third compression mechanism (130) and the fourth compression mechanism (140) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other compression mechanism allow uncompressed refrigerant to pass through the other compression mechanism.

[0041] In the seventeenth aspect of the invention, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, it is switched between the state in which refrigerant is compressed in both of the third compression mechanism (130) and the fourth compression mechanism (140) to provide the difference between the suction pressure and the discharge pressure, and the state in which refrigerant is compressed in one of the third compression mechanism (130) and the fourth compression mechanism (140) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other compression mechanism allow uncompressed refrigerant to pass through the other compression mechanism. Thus, the volume ratio can be adjusted between the two operational states.

[0042] An eighteenth aspect of the invention is intended for the refrigerating apparatus of the thirteenth aspect of the invention, in which the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in both of the low-pressure and high-pressure compression mechanisms to provide a difference between a suction pressure and a discharge pressure, and a state in which, when the first compression mechanism (110) is at the low-pressure stage, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in the low-pressure compression mechanism to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140) at the high-pressure stage allow uncompressed refrigerant to pass through the one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140).

[0043] In the eighteenth aspect of the invention, it is switched between the state in which, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in both of the low-pressure and high-pressure compression mechanisms to provide the difference between the suction pressure and the discharge pressure, and the state in which, when the first compression mechanism (110) is at the low-pressure stage, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in the low-pressure compression mechanism to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140) at the high-pressure stage allow uncompressed refrigerant to pass through the one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140). Thus, the volume ratio can be adjusted between the two operational states.

[0044] A nineteenth aspect of the invention is intended for the refrigerating apparatus of the thirteenth aspect of the invention, in which, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in parallel, and a state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in series.

[0045] In the nineteenth aspect of the invention, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, it is switched between the state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in parallel, and the state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in series. Thus, the volume ratio can be adjusted between the two operational states.

[0046] A twentieth aspect of the invention is intended for the refrigerating apparatus of the thirteenth aspect of the invention, in which, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in parallel, and a state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in series.

[0047] In the twentieth aspect of the invention, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, it is switched between the state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in parallel, and the state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in series. Thus, the volume ratio can be adjusted between the two operational states.

[0048] A twenty-first aspect of the invention is intended for the refrigerating apparatus of any one of the thirteenth to twentieth aspects of the invention, in which the switching mechanism (107, 108) is a switching valve configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110, 120, 130, 140).

[0049] In the twenty-first aspect of the invention, the flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant is switched by the switching valve (107, 108), thereby adjusting the volume ratio of the compressor (1) depending on the different operational states.

[0050] A twenty-second aspect of the invention is intended for the refrigerating apparatus of any one of the thirteenth to twenty-first aspects of the invention, in which the volume ratio changing unit (107) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

[0051] In the twenty-second aspect of the invention, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism is adjusted depending on the change in operational conditions.

[0052] A twenty-third aspect of the invention is intended for the refrigerating apparatus of any one of the first to twenty-second aspects of the invention, in which refrigerant is carbon dioxide.

[0053] In the twenty-third aspect of the invention, the volume ratio can be adjusted in the compressor in which refrigerant is carbon dioxide.

ADVANTAGES OF THE INVENTION

[0054] According to the present invention, in the refrigerating apparatus including the compressor (1) in which the plurality of compression mechanisms (20, 30) are mechanically connected together through the single drive shaft (53) to compress refrigerant at the two stages, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism can be adjusted. Thus, an operation with optimum COP is realized. A change in volume ratio changes a compression torque, thereby adjusting a compression torque variation.

[0055] According to the second aspect of the invention, e.g., the combination of the cylinder chambers to be used as the low-pressure compression mechanism and the cylinder chambers to be used as the high-pressure compression mechanism is changed while performing the operation. Thus, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism can be adjusted, thereby realizing the operation with optimum COP.

[0056] According to the third aspect of the invention, in the configuration in which each of the two compression mechanisms (20, 30) provided in the compressor (1) includes the two cylinder chambers (C1, C2), (C3, C4) on the outer and inner circumferential sides of the circular pistons (22, 32), the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism can be adjusted, thereby realizing the operation with optimum COP.

[0057] For example, a case is considered, where the suction volume ratio is adjusted by unloading the low-pressure or high-pressure compression mechanism in the two-stage compression mechanism. However, unlike such an example, refrigerant is not compressed in the middle of a compression stroke in the present embodiment, thereby realizing a smooth operation.

[0058] According to the fourth aspect of the invention, since the inner cylinder chambers (C2, C4) on the inner circumferential side of the circular pistons (22, 32) and the outer cylinder chambers (C1, C3) on the outer circumferential side of the circular pistons (22, 32) have the volumes different from each other, the two compression mechanisms (20, 30) are configured so that the inner cylinder chambers (C2, C4) have the same volume, and the outer cylinder chambers (C1, C3) have the same volume. Thus, the compression mechanisms (20, 30) can be easily realized, which include the four cylinder chambers (C1, C2, C3, C4) set to at least two suction volume levels.

[0059] According to the fifth aspect of the invention, the lengths of the cylinder chambers (C1, C2, C3, C4) in a shaft direction are adjusted, and therefore the suction volumes of the four cylinder chambers (C1, C2, C3, C4) can be easily differentiated. The volumes of the four cylinder chambers (C1, C2, C3, C4) are different from each other, and therefore the number of the combination patterns of the cylinder chambers (C1, C2, C3, C4) for changing the volume ratio can be increased to maximum. Thus, the operation with optimum COP can be realized depending on various operational conditions.

[0060] According to the sixth aspect of the invention, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, it is switched between the state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected in parallel and the state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected in series. Thus, the volume ratio can be adjusted between two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0061] According to the seventh aspect of the invention, it is switched between the state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and the state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) and one of the cylinder chambers (C4) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C3) of the second compression mechanism (30) is used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0062] According to the eighth aspect of the invention, it is switched between the state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and the state in which one of the cylinder chambers (C1) of the first compression mechanism (20) and one of the cylinder chambers (C3) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C2) of the first compression mechanism (20) and the other cylinder chamber (C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0063] According to the ninth aspect of the invention, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, it is switched between the state in which refrigerant is compressed in both of the cylinder chambers (C3, C4) of the second compression mechanism (30), and the state in which refrigerant is compressed only in one of the cylinder chambers (C3), (C4) of the second compression mechanism (30), and uncompressed refrigerant passes through the other cylinder chamber (C4), (C3). Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0064] According to the tenth aspect of the invention, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, it is switched between the state in which refrigerant is compressed in both of the cylinder chambers (C1, C2) of the first compression mechanism (20), and the state in which refrigerant is compressed only in one of the cylinder chambers (C1), (C2) of the first compression mechanism (20), and uncompressed refrigerant passes through the other cylinder chamber (C2), (C1). Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0065] According to the eleventh aspect of the invention, the flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant is switched by the switching valve, thereby adjusting the volume ratio of the compressor (1) depending on the different operational states. Thus, the adjustment of the volume ratio of the compressor (1) can be realized with a simple configuration.

[0066] According to the twelfth aspect of the invention, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism is adjusted depending on the change in operational conditions. Thus, the operation with optimum COP can be realized depending on, e.g., a change in external air temperature.

[0067] According to the thirteenth aspect of the invention, in the configuration in which each of the four compression mechanisms (110, 120, 130, 140) provided in the compressor (1) includes the cylinder (111, 121, 131, 141) with the circular cylinder space, and the eccentric piston (112, 122, 132, 142) eccentrically rotating in the cylinder space, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism is adjusted, thereby realizing the operation with optimum COP. A case is considered, where the suction volume ratio is adjusted by unloading the low-pressure or high-pressure compression mechanism in the two-stage compression mechanism. However, unlike such a case, refrigerant is not compressed in the middle of the compression stroke in the present embodiment, thereby realizing the smooth operation.

[0068] According to the fourteenth aspect of the invention, it is switched between the state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and the state in which the first compression mechanism (110), the second compression mechanism (120), and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the fourth compression mechanism (140) is used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0069] According to the fifteenth aspect of the invention, it is switched between the state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and the state in which the first compression mechanism (110) is used as the low-pressure compression mechanism, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0070] According to the sixteenth aspect of the invention, in the configuration in which the cylinder volume of at least one of the compression mechanisms is different from the cylinder volumes of the other compression mechanisms, it is switched between the state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and the state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0071] According to the seventeenth aspect of the invention, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, it is switched between the state in which refrigerant is compressed in both of the third compression mechanism (130) and the fourth compression mechanism (140) to provide the difference between the suction pressure and the discharge pressure, and the state in which refrigerant is compressed in one of the third compression mechanism (130) and the fourth compression mechanism (140) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other compression mechanism allow uncompressed refrigerant to pass through the other compression mechanism. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0072] According to the eighteenth aspect of the invention, it is switched between the state in which, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in both of the low-pressure and high-pressure compression mechanisms to provide the difference between the suction pressure and the discharge pressure, and the state in which, when the first compression mechanism (110) is at the low-pressure stage, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in the low-pressure compression mechanism to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140) at the high-pressure stage allow uncompressed refrigerant to pass through the one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140). Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0073] According to the nineteenth aspect of the invention, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, it is switched between the state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in parallel, and the state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in series. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0074] According to the twentieth aspect of the invention, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, it is switched between the state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in parallel, and the state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in series. Thus, the volume ratio can be adjusted between the two operational states. Consequently, the operation with optimum COP can be realized depending on the different operational states.

[0075] According to the twenty-first aspect of the invention, the flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant is switched by the switching valve, thereby adjusting the volume ratio of the compressor (1) depending on the different operational states. Thus, the adjustment of the volume ratio of the compressor (1) can be realized with a simple configuration.

[0076] According to the twenty-second aspect of the invention, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism is adjusted depending on the change in operational conditions. Thus, the operation with optimum COP can be realized depending on, e.g., a change in external air temperature.

[0077] According to the twenty-third aspect of the invention, refrigerant is carbon dioxide. This provides a noticeable effect in the two-stage compression as compared to other refrigerant, thereby increasing a COP improvement effect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0078]

[FIG. 1] FIG. 1 is a longitudinal sectional view of a compressor used for an air conditioning apparatus of a first embodiment.

[FIG. 2] FIG. 2 is a cross-sectional view of a compression mechanism of the first embodiment.

[FIG. 3] FIGS. 3(A)-3(H) are views illustrating operational states in the compression mechanism of the first embodiment.

[FIG. 4] FIG. 4 is a refrigerant circuit diagram illustrating a first operational state of the air conditioning apparatus of the first embodiment.

[FIG. 5] FIG. 5 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the first embodiment.

[FIG. 6] FIG. 6 is a cross-sectional view illustrating a first operational state switching pattern of a variation of the first embodiment.

[FIG. 7] FIG. 7 is a cross-sectional view illustrating a second operational state switching pattern of the variation of the first embodiment.

[FIG. 8] FIG. 8 is a cross-sectional view illustrating a third operational state switching pattern of the variation of the first embodiment.

[FIG. 9] FIG. 9 is a cross-sectional view illustrating a fourth operational state switching pattern of the variation of the first embodiment.

[FIG. 10] FIG. 10 is a cross-sectional view illustrating a fifth operational state switching pattern of the variation of the first embodiment.

[FIG. 11] FIG. 11 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a second embodiment.

[FIG. 12] FIG. 12 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the second embodiment.

[FIG. 13] FIG. 13 is a cross-sectional view illustrating a first operational state switching pattern of a variation of the second embodiment.

[FIG. 14] FIG. 14 is a cross-sectional view illustrating a second operational state switching pattern of the variation of the second embodiment.

[FIG. 15] FIG. 15 is a cross-sectional view illustrating a third operational state switching pattern of the variation of the second embodiment.

[FIG. 16] FIG. 16 is a cross-sectional view illustrating a fourth operational state switching pattern of the variation of the second embodiment.

[FIG. 17] FIG. 17 is a cross-sectional view illustrating a fifth operational state switching pattern of the variation of the second embodiment.

[FIG. 18] FIG. 18 is a cross-sectional view illustrating a sixth operational state switching pattern of the variation of the second embodiment.

[FIG. 19] FIG. 19 is a cross-sectional view illustrating a seventh operational state switching pattern of the variation of the second embodiment.

[FIG. 20] FIG. 20 is a cross-sectional view illustrating an eighth operational state switching pattern of the variation of the second embodiment.

[FIG. 21] FIG. 21 is a cross-sectional view illustrating a ninth operational state switching pattern of the variation of the second embodiment.

[FIG. 22] FIG. 22 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a third embodiment.

[FIG. 23] FIG. 23 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the third embodiment.

[FIG. 24] FIG. 24 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a fourth embodiment.

[FIG. 25] FIG. 25 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the fourth embodiment.

[FIG. 26] FIG. 26 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a fifth embodiment.

[FIG. 27] FIG. 27 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the fifth embodiment.

[FIG. 28] FIG. 28 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a sixth embodiment.

[FIG. 29] FIG. 29 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the sixth embodiment.

[FIG. 30] FIG. 30 is a longitudinal sectional view of a compressor used for a refrigerating apparatus (air conditioning apparatus) of a seventh embodiment.

[FIG. 31] FIG. 31 is a cross-sectional view of a compression mechanism of the seventh embodiment.

[FIG. 32] FIGS. 32(A)-32(D) are views illustrating operational states in the compression mechanism of the seventh embodiment.

[FIG. 33] FIG. 33 is a refrigerant circuit diagram illustrating a first operational state of the air conditioning apparatus of the seventh embodiment.

[FIG. 34] FIG. 34 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the seventh embodiment.

[FIG. 35] FIG. 35 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of an eighth embodiment.

[FIG. 36] FIG. 36 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the eighth embodiment.

[FIG. 37] FIG. 37 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a ninth embodiment.

[FIG. 38] FIG. 38 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the ninth embodiment.

[FIG. 39] FIG. 39 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a tenth embodiment.

[FIG. 40] FIG. 40 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the tenth embodiment.

[FIG. 41] FIG. 41 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of an eleventh embodiment.

[FIG. 42] FIG. 42 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the eleventh embodiment.

[FIG. 43] FIG. 43 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a twelfth embodiment.

[FIG. 44] FIG. 44 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the twelfth embodiment.

[FIG. 45] FIG. 45 is a refrigerant circuit diagram illustrating a first operational state of an air conditioning apparatus of a thirteenth embodiment.

[FIG. 46] FIG. 46 is a refrigerant circuit diagram illustrating a second operational state of the air conditioning apparatus of the thirteenth embodiment.

[FIG. 47] FIG. 47 is a cross-sectional view illustrating a variation in which an internal pressure of a casing is at a high pressure level.

[FIG. 48] FIG. 48 is a cross-sectional view illustrating a variation in which the internal pressure of the casing is at an intermediate pressure level.

[FIG. 49] FIG. 49 is a cross-sectional view illustrating a first variation of a combination of suction and discharge ports.

[FIG. 50] FIG. 50 is a cross-sectional view illustrating a second variation of the combination of the suction and discharge ports.

[FIG. 51] FIG. 51 is a cross-sectional view illustrating a third variation of the combination of the suction and discharge ports.

[FIG. 52] FIG. 52 is a cross-sectional view illustrating a fourth variation of the combination of the suction and discharge ports.

[FIG. 53] FIG. 53 is a cross-sectional view illustrating a fifth variation of the combination of the suction and discharge ports.

[FIG. 54] FIG. 54 is a cross-sectional view illustrating a sixth variation of the combination of the suction and discharge ports.

[FIG. 55] FIG. 55 is a cross-sectional view illustrating a seventh variation of the combination of the suction and discharge ports.

[FIG. 56] FIG. 56 is a cross-sectional view illustrating an eighth variation of the combination of the suction and discharge ports.

[FIG. 57] FIG. 57 is a cross-sectional view illustrating a ninth variation of the combination of the suction and discharge ports.

[FIG. 58] FIG. 58 is a cross-sectional view illustrating a tenth variation of the combination of the suction and discharge ports.

[FIG. 59] FIG. 59 is a cross-sectional view illustrating an eleventh variation of the combination of the suction and discharge ports.

[FIG. 60] FIG. 60 is a cross-sectional view illustrating a twelfth variation of the combination of the suction and discharge ports.

[FIG. 61] FIG. 61 is a cross-sectional view illustrating a thirteenth variation of the combination of the suction and discharge ports.

[FIG. 62] FIG. 62 is a cross-sectional view illustrating a fourteenth variation of the combination of the suction and discharge ports.

DESCRIPTION OF EMBODIMENTS

[0079] Embodiments of the present invention will be described below in detail with reference to the drawings.

<<First Embodiment of the Invention>>

[0080] A first embodiment of the present invention will be described.

[0081] FIG. 1 is a longitudinal sectional view of a compressor (1) used for a refrigerating apparatus (air conditioning apparatus) of the first embodiment, FIG. 2 is a cross-sectional view of a compression mechanism (first compression mechanism), and FIGS. 3(A)-3(H) are views illustrating operational states in the compression mechanism (first compression mechanism). In addition, FIG. 4 is a refrigerant circuit diagram illustrating a first operational state of the air conditioning apparatus, and FIG. 5 is a refrigerant circuit diagram illustrating a second operational state. In a refrigerant circuit of the air conditioning apparatus, the compressor (1) is used for compressing refrigerant sucked from an evaporator, and discharging such refrigerant to a condenser.

<Configuration of Compressor>

[0082] First, a configuration of the compressor (1) will be described. The compressor (1) is a rotary compressor, and includes a first compression mechanism (20) and a second compression mechanism (30) which are mechanically connected together through a single drive shaft (53). The compressor (1) is configured so that carbon dioxide which is refrigerant (working fluid) is compressed at two stages. That is, the first compression mechanism (20) and the second compression mechanism (30) form a two-stage compression mechanism. Since the cross-sectional view and the operational state view of the second compression mechanism (30) are the substantially same as those of the first compression mechanism (20), reference numerals of the second compression mechanism (30) are shown in FIG. 2 without details. The first compression mechanism (20) and the second compression mechanism (30) are arranged so that their phases are shifted by 180°.

[0083] As illustrated in FIG. 1, the compressor (1) includes a casing (10) in which the first compression mechanism (20), the second compression mechanism (30), and an electrical motor (drive mechanism) (50) are accommodated; and is hermetic. In the present embodiment, the first compression mechanism (20) serves as a low-pressure compression mechanism, and the second compression mechanism (30) serves as a high-pressure compression mechanism.

[0084] The casing (10) includes a cylindrical body section (11), an upper end plate (12) fixed to an upper end portion of the body section (11), and a lower end plate (13) fixed to a lower end portion of the body section (11). In a lower portion of the body section (11), a first suction port pipe (14-1) and a first discharge port pipe (15-1) are provided as a suction port pipe for a first outer cylinder chamber (described later) and a discharge port pipe for a first inner cylinder chamber (described later) in the first compression mechanism (20). In a portion of the body section (11) slightly above the first suction port pipe (14-1), a second suction port pipe (14-2) is provided as a suction port pipe of the second compression mechanism (30). The second suction port pipe (14-2) includes two suction port pipes, i.e., a second suction port a-pipe (14-2a) for a later-described second outer cylinder chamber, and a second suction port b-pipe (14-2b) for a later-described second inner cylinder chamber. Each of two second discharge port pipes (15-2) is provided in the body section (11) and the upper end plate (12). A second discharge port a-pipe (15-2a) for the outer cylinder chamber is provided in a lower portion of the body section (11) relative to the middle of the body section (11), and a second discharge port b-pipe (15-2b) for the inner cylinder chamber is provided in an upper portion of the body section (11).

[0085] A summary of configurations of the suction port pipes (14a, 14b) and the discharge port pipes (15a, 15b) is as follows. That is, the first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). The first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The second suction port pipe (14-2) includes the second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and the second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). The second discharge port pipe (15-2) includes the second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and the second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4) by way of a space inside the casing (10).

[0086] The first compression mechanism (20) and the second compression mechanism (30) are stacked in two tiers, and are interposed between a front head (16) and a rear head (17) which are fixed to the casing (10). Note that the second compression mechanism (30) is arranged on an electrical motor side (upper side as viewed in FIG. 1), and the first compression mechanism (20) is arranged on a bottom side of the casing (10) (lower side as viewed in FIG. 1). A middle plate (19) is provided between the front head (16) and the rear head (17).

[0087] As illustrated in FIG. 2, the first compression mechanism (20) includes a first cylinder (21) having a first circular cylinder chamber (C1, C2); a first circular piston (22) arranged inside the first cylinder chamber (C1, C2); and a first blade (23) dividing the first cylinder chamber (C1, C2) into a high-pressure chamber (compression chamber) (C1-Hp, C2-Hp) which is a first chamber, and a low-pressure chamber (suction chamber) (C1-Lp, C2-Lp) which is a second chamber as illustrated in FIGS. 2 and 3.

[0088] On the other hand, the second compression mechanism (30) has a reversed shape of the first compression mechanism (20). The second compression mechanism (30) includes a second cylinder (31) having a second circular cylinder chamber (C3, C4); a second circular piston (32) arranged inside the second cylinder chamber (C3, C4); and a second blade (33) dividing the second cylinder chamber (C3, C4) into a high-pressure chamber (not shown in the figure) which is a first chamber, and a low-pressure chamber (not shown in the figure) which is a second chamber.

[0089] In the present embodiment, the front head (16) serves as the second cylinder (31), and the rear head (17) serves as the first cylinder (21). In addition, in the present embodiment, the first cylinder (21) having the first cylinder chamber (C1, C2) and the second cylinder (31) having the second cylinder chamber (C3, C4) are fixed, and the first circular piston (22) and the second circular piston (32) are movable. The first circular piston (22) eccentrically rotates in the first cylinder (21), and the second circular piston (32) eccentrically rotates in the second cylinder (31).

[0090] The electrical motor (50) includes a stator (51) and a rotor (52). The stator (51) is arranged above the second compression mechanism (30), and is fixed to the body section (11) of the casing (10). The drive shaft (crankshaft) (53) is connected to the rotor (52), and rotates together with the rotor (52). The drive shaft (53) vertically penetrates the first cylinder chamber (C1, C2) and the second cylinder chamber (C3, C4). Typically, an oil supply structure using an oil supply path extending in a shaft direction inside the drive shaft (53) is employed in the compressor (1), but the oil supply structure is omitted in the present embodiment.

[0091] In the drive shaft (53), a first eccentric section (53a) is formed in a portion positioned in the first cylinder chamber (C1, C2), and a second eccentric section (53b) is formed in a portion positioned in the second cylinder chamber (C3, C4). The first eccentric section (53a) is formed so as to have a diameter larger than that of a main shaft portion above and below the first eccentric section (53a), and is eccentric from the center of the drive shaft (53) by a predetermined distance. The second eccentric section (53b) is formed so as to have the same diameter as that of the first eccentric section (53a), and is eccentric from the center of the drive shaft (53) by the same distance as that of the first eccentric section (53a). The first eccentric section (53a) and the second eccentric section (53b) have phases shifted from each other by 180° about the center of the drive shaft (53).

[0092] The first circular piston (22) is an integrally-formed member. The first circular piston (22) includes a first bearing section (22a) slidably fitted on the first eccentric section (53a) of the drive shaft (53), a first circular piston body section (22b) positioned concentric to the first bearing section (22a) on an outer circumferential side of the first bearing section (22a), and a first piston-side end plate (22c) connecting between the first bearing section (22a) and the first circular piston body section (22b). The first circular piston body section (22b) is formed in C-shape, i.e., a part of the annular ring splits (see FIG. 2).

[0093] As in the first circular piston (22), the second circular piston (32) is an integrally-formed member. The second circular piston (32) includes a second bearing section (32a) slidably fitted on the second eccentric section (53b) of the drive shaft (53), a second circular piston body section (32b) positioned concentric to the second bearing section (32a) on an outer circumferential side of the second bearing section (32a), and a second piston-side end plate (32c) connecting between the second bearing section (32a) and the second circular piston body section (32b). The second circular piston body section (32b) is formed in C-shape, i.e., a part of the annular ring splits (see FIG. 2).

[0094] The first cylinder (21) includes a first inner cylinder section (21b) positioned concentric to the drive shaft (53) between the first bearing section (22a) and the first circular piston body section (22b), a first outer cylinder section (21a) positioned concentric to the first inner cylinder section (21 b) on an outer circumferential side of the first circular piston body section (22b), and a first cylinder-side end plate (21c) connecting between the first inner cylinder section (21b) and the first outer cylinder section (21a).

[0095] The second cylinder (31) includes a second inner cylinder section (31 b) positioned concentric to the drive shaft (53) between the second bearing section (32a) and the second circular piston body section (32b), a second outer cylinder section (31 a) positioned concentric to the second inner cylinder section (31 b) on an outer circumferential side of the second circular piston body section (32b), and a second cylinder-side end plate (31c) connecting between the second inner cylinder section (31b) and the second outer cylinder section (31a).

[0096] Bearing sections (16a, 17a) supporting the drive shaft (53) are formed in the front head (16) and the rear head (17), respectively. The compressor (1) of the present embodiment has a through-shaft structure in which the drive shaft (53) vertically penetrates the first cylinder chamber (C1, C2) and the second cylinder chamber (C3, C4), and both side portions of the first eccentric section (53a) and the second eccentric section (53b) in the shaft direction are held by the casing (10) through the bearing sections (16a, 17a).

[0097] Next, an internal structure of the first and second compression mechanisms (20, 30) will be described. The first and second compression mechanisms (20, 30) have the substantially same configuration, except that, in order to change a cylinder volume, the length of the circular piston (22, 32) in the shaft direction and the length of the corresponding cylinder (21, 31) in the shaft direction are different between the first and second compression mechanisms (20, 30). Thus, the first compression mechanism (20) will be described as a representative example.

[0098] As illustrated in FIG. 2, the first compression mechanism (20) includes a first swing bush (27) as a connecting member swingably connecting the first circular piston (22) to first blade (23) at the split portion of the first circular piston (22). The first blade (23) extends from an inner circumferential wall surface of the first cylinder chamber (C1, C2) (outer circumferential surface of the first inner cylinder section (21b)) to an outer circumferential wall surface of the first cylinder chamber (C1, C2) (inner circumferential surface of the first outer cylinder section (21a)) through the split portion of the first circular piston (22) in a radial direction of the first cylinder chamber (C1, C2). The first blade (23) is fixed to the first outer cylinder section (21a) and the first inner cylinder section (21b). Note that the first blade (23) may be integrally formed with the first outer cylinder section (21a) and the first inner cylinder section (21b), or another member may be attached to both of the cylinder sections (21a, 21b). The example illustrated in FIG. 2 is an example where another member is fixed to both of the cylinder sections (21a, 2 1 b).

[0099] The inner circumferential surface of the first outer cylinder section (21 a) and the outer circumferential surface of the first inner cylinder section (21 b) are cylindrical surfaces arranged concentric to each other, and the first cylinder chamber (C1, C2) is formed between the inner circumferential surface of the first outer cylinder section (21 a) and the outer circumferential surface of the first inner cylinder section (21b). The first circular piston (22) is formed so that an outer circumferential surface of the first circular piston (22) has a diameter smaller than that of the inner circumferential surface of the first outer cylinder section (21 a), and an inner circumferential surface of the first circular piston (22) has a diameter larger than that of the outer circumferential surface of the first inner cylinder section (21b). Thus, the first outer cylinder chamber (C1) is formed between the outer circumferential surface of the first circular piston (22) and the inner circumferential surface of the first outer cylinder section (21a), and the first inner cylinder chamber (C2) is formed between the inner circumferential surface of the first circular piston (22) and the outer circumferential surface of the first inner cylinder section (21 b). That is, the compressor (1) includes the first compression mechanism (20) and the second compression mechanism (30), each of which has the two compression chambers (C1, C2), (C3, C4). Each of the compression mechanisms (20, 30) includes the cylinder (21, 31) with the circular cylinder space, and the circular piston (22, 32) eccentrically rotating in the cylinder space. In the cylinder space, the inner cylinder chamber (C2, C4) is formed on an inner circumferential side of the circular piston (22, 32), and the outer cylinder chamber (C1, C3) is formed on an outer circumferential side of the circular piston (22, 32).

[0100] Specifically, the first outer cylinder chamber (C1) is defined by the first cylinder-side end plate (21 c), the first piston-side end plate (22c), the first outer cylinder section (21 a), and the first circular piston body section (22b). The first inner cylinder chamber (C2) is defined by the first cylinder-side end plate (21 c), the first piston-side end plate (22c), the first inner cylinder section (21b), and the first circular piston body section (22b). A space (25) where the eccentric rotation of the first bearing section (22a) is allowed on an inner circumferential side of the first inner cylinder section (21b) is defmed by the first cylinder-side end plate (21 c), the first piston-side end plate (22c), the first bearing section (22a) of the first circular piston (22), and the first inner cylinder section (21b) (see FIG. 2).

[0101] In a state in which the outer circumferential surface of the first circular piston (22) and the inner circumferential surface of the first outer cylinder section (21 a) substantially contact each other at one point (i.e., a state in which, even if there is a micron-order space, no disadvantage is caused due to refrigerant leakage in such a space), the first circular piston (22) and the first cylinder (21) are configured so that the inner circumferential surface of the first circular piston (22) and the outer circumferential surface of the first inner cylinder section (21 b) substantially contact each other at one point which is shifted from the foregoing contact point by 180°.

[0102] The first swing bush (27) includes an outlet-side bush (27A) positioned on the high-pressure chamber (intermediate-pressure chamber) (C1-Hp, C2-Hp) side relative to the first blade (23), and an inlet-side bush (27B) positioned on the low-pressure chamber (C1-Lp, C2-Lp) side relative to the first blade (23). The outlet-side bush (27A) and the inlet-side bush (27B) are formed in the same shape having a substantially semicircular cross section, and flat surfaces of the outlet-side bush (27A) and the inlet-side bush (27B) are arranged so as to face each other. A space between the opposing surfaces of both of the bushes (27A, 27B) forms a blade groove (28).

[0103] The first blade (23) is inserted into the blade groove (28). Thus, the flat surfaces of the first swing bushes (27A, 27B) are in substantial surface contact with the first blade (23), and arc-shaped outer circumferential surfaces of the first swing bushes (27A, 27B) are in substantial surface contact with the first circular piston (22). The first swing bushes (27A, 27B) move back and forth along surfaces of the first blade (23) with the first blade (23) being inserted into the blade groove (28). In addition, the first swing bushes (27A, 27B) are configured so that the first circular piston (22) swings relative to the first blade (23). Thus, the first swing bush (27) is configured so that the first circular piston (22) can swing relative to the first blade (23) about a swing center, i.e., a center point of the first swing bush (27), and the first circular piston (22) can move back and forth along the surfaces of the first blade (23).

[0104] In the present embodiment, the example has been described, where the bushes (27A, 27B) are separated members. However, the bushes (27A, 27B) may have an integrated structure by partially connecting to each other.

[0105] In the foregoing configuration, when rotating the drive shaft (53), the first circular piston (22) moves back and forth along the first blade (23) and swings about the swing center, i.e., the center point of the first swing bush (27) together with the first swing bush (27). In addition, when rotating the drive shaft (53), the second circular piston (32) also swings about a swing center, i.e., a center point of a second swing bush (37) as in the first circular piston (22).

[0106] Such a swing continuously moves a first contact point between the first circular piston (22) and the first cylinder (21) as illustrated from FIG. 3(A) to FIG. 3(H). On the other hand, a second contact point between the second circular piston (32) and the second cylinder (31) is shifted from the first contact point by 180° about the center of the drive shaft (53). That is, as viewed from above the drive shaft (53), when the operational state in the first compression mechanism (20) is as illustrated in FIG. 3(A), the operational state in the second compression mechanism (30) is as illustrated in FIG. 3(E).

[0107] FIGS. 3(A)-3(H) are the views illustrating the operational states in the first compression mechanism (20), and illustrate a state in which the first circular piston (22) moves at 45° interval in a clockwise direction as viewed in FIGS. 3(A)-3(H). In such a state, the first circular piston (22) revolves about the drive shaft (53), but does not rotate.

[0108] The first compression mechanism (20) includes the first suction port pipe (14-1) through which low-pressure refrigerant is sucked, and the first discharge port pipe (15-1) through which intermediate-pressure refrigerant is discharged. A first inlet (41 a) to be connected to the first suction port pipe (14-1) is formed in the rear head (17). The first inlet (41a) of the rear head (17) is communicated with the low-pressure chambers of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2) through a first injection path (42a). The first suction port pipe (14-1) is fixed to the rear head (17), and is communicated with the cylinder chamber (C1, C2) of the first compression mechanism (20).

[0109] An intermediate discharge space (17b) communicating with the cylinder chamber (C1, C2) of the first compression mechanism (20) is formed in the rear head (17). Intermediate-pressure refrigerant compressed in the first compression mechanism (20) is discharged to the intermediate discharge space (17b) through an outer outlet (45a) and an inner outlet (46a) which are illustrated in FIG. 2 and a discharge valve (not shown in the figure, but a discharge valve holder (47) is illustrated in the figure) configured to open/close the outer outlet (45 a) and the inner outlet (46a). The first discharge port pipe (15-1) penetrating the body section (11) of the casing (10) is fixed to the rear head (17). An inner end portion of the first discharge port pipe (15-1) opens to the intermediate discharge space (17b) of the rear head (17), and an outer end portion of the first discharge port pipe (15-1) is connected to an intermediate-pressure refrigerant pipe (not shown in FIG. 1) of the refrigerant circuit.

[0110] The second compression mechanism (30) includes the second suction port pipe (14-2) through which intermediate-pressure refrigerant is sucked. The second suction port pipe (14-2) includes the second suction port a-pipe (14-2a) for the outer cylinder chamber (C3), and the second suction port b-pipe (14-2b) for the inner cylinder chamber (C4). In the front head (16), a second inlet (41b-1) to be connected to the second suction port a-pipe (14-2a) is formed so as to be communicated with the low-pressure chamber of the second outer cylinder chamber (C3), and a second inlet (41b-2) to be connected to the second suction port b-pipe (14-2b) is formed so as to be communicated with the low-pressure chamber of the second inner cylinder chamber (C4). The second suction port pipe (14-2) is fixed to the front head (16), and is communicated with the cylinder chambers (C3, C4) of the second compression mechanism (30).

[0111] High-pressure refrigerant compressed in the cylinder chambers (C3, C4) of the second compression mechanism (30) is discharged to discharge spaces (49a, 49b) through outlets (45b, 46b) of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) and a discharge valve (not shown in the figure, but a discharge valve holder (48) is illustrated in the figure). The second discharge port a-pipe (15-2a) for the outer cylinder chamber (C3) is connected to the outer discharge space (49a). The inner discharge space (49b) is communicated with the space inside the casing (10). Gas refrigerant in the casing (10) is discharged to a high-pressure gas pipe of the refrigerant circuit through the second discharge port b-pipe (15-2b) provided in an upper portion of the casing (10).

[0112] In the first embodiment, the first compression mechanism (20) and the second compression mechanism (30) form the two-stage compression mechanism, and a cylinder volume of the second compression mechanism (30) at the high-pressure stage is smaller than a cylinder volume of the first compression mechanism (20) at the low-pressure stage. To this end, the length of the second circular piston body section (32b) in the shaft direction is shorter than the length of the first circular piston body section (22b) in the shaft direction. According to the foregoing configuration, volumes of the four cylinder chambers are different from each other in the present embodiment.

<Configuration of Refrigerant Circuit>

[0113] In a refrigerant circuit (60) of the air conditioning apparatus, carbon dioxide which is refrigerant is compressed to a supercritical pressure level by the compressor (1), thereby performing a refrigeration cycle. As illustrated in FIG. 4, the refrigerant circuit (60) includes the compressor (1), a gas cooler (2), an evaporator (3), a gas-liquid separator (4), a first expansion valve (5), and a second expansion valve (6). In addition, in the refrigerant circuit, two three-way valves (switching valves) (7) are provided.

[0114] The first suction port pipe (14-1) of the compressor (1) is connected to a gas-side end of the evaporator (3) through a first suction pipe (61). The first discharge port pipe (15-1) of the compressor (1) is connected to a refrigerant gas outlet (4a) of the gas-liquid separator (4) through a first discharge pipe (63). An outlet (4c) of the gas-liquid separator (4) is connected to a liquid-side end of the evaporator (3) through a liquid pipe (66) including the second expansion valve (6) in the middle thereof.

[0115] The second discharge port b-pipe (15-2b) of the compressor (1) is connected to a second discharge pipe (64b). The second discharge pipe (64b) is connected to an inlet (4b) of the gas-liquid separator (4) through the gas cooler (2) and the first expansion valve (5).

[0116] The second discharge port a-pipe (15-2a) of the compressor is connected to a first port (P1) of the first three-way valve (7a) through a second discharge pipe (64a). A connecting pipe (67a) is connected to a second port (P2) of the first three-way valve (7a), and the connecting pipe (67a) joins the second discharge pipe (64b) upstream the gas cooler (2). A third port (P3) of the first three-way valve (7a) is connected to a second port (P2) of the second three-way valve (7b) through an intermediate suction pipe (65) including a muffler (9).

[0117] The first discharge pipe (63) branches into a branched pipe (68) in the middle thereof. The branched pipe (68) is connected to the second suction port a-pipe (14-2a) of the second compression mechanism (30) through a second suction pipe (62a) including the muffler (9), and has a function of an injection pipe configured to inject intermediate-pressure refrigerant to the compressor (1). A third port (P3) of the second three-way valve (7b) is connected to second suction pipe (62a) downstream the muffler (9). A first port (P1) of the second three-way valve (7b) is connected to the second suction port b-pipe (14-2b) of the second compression mechanism (30) through a second suction pipe (62b).

[0118] The three-way valve (7) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other, and a second position in which the first port (P1) and the third port (P3) are communicated with each other.

[0119] The three-way valve (7) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into the compression mechanism (20, 30). The three-way valve (7) is configured so that, by changing a connection order of the four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (60), a ratio of a suction volume of the low-pressure compression mechanism (20) to a suction volume of the high-pressure compression mechanism (30) is changed. That is, the switching mechanism (7) switches the four cylinder chambers (C1, C2, C3, C4) so that some of the cylinder chambers are used as the low-pressure compression mechanism (20), and the remaining cylinder chambers are used as the high-pressure compression mechanism (30).

[0120] In addition, for the first compression mechanism (20) at the low-pressure stage and the second compression mechanism (30) at the high-pressure stage, the three-way valve (7) is switchable between a state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected together in parallel, and a state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected together in series.

[0121] The switching mechanism (volume ratio changing unit) (7) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

<Operation of Compressor>

[0122] Next, an operation of the compressor (1) will be described. A process is carried out in the first and second compression mechanisms (20, 30) in a state in which the phases of the first and second compression mechanisms (20, 30) are shifted from each other by 180°.

[0123] When starting the electrical motor (50), rotation of the rotor (52) is transmitted to the first circular piston (22) through the drive shaft (53) in the first compression mechanism (20) which is the low-pressure compression mechanism. Then, the first swing bushes (27A, 27B) reciprocate (move back and forth) along the first blade (23), and the first circular piston (22) and the first swing bushes (27A, 27B) together swing relative to the first blade (23). In such a state, the first swing bushes (27A, 27B) are in substantial surface contact with the first circular piston (22) and the first blade (23). The first circular piston (22) revolves while swinging relative to the first outer cylinder section (21 a) and the first inner cylinder section (21b). Thus, the first compression mechanism (20) carries out a predetermined compression process.

[0124] Specifically, in the first outer cylinder chamber (C1), the volume of the low-pressure chamber (C1-Lp) is substantially minimum in the state illustrated in FIG. 3 (B). Starting from such a state, the volume of the low-pressure chamber (C1-Lp) is increased as the state illustrated in FIG. 3(C) is changed to the state illustrated in FIG. 3(A) by rotating the drive shaft (53) clockwise as viewed in the figure. Then, refrigerant is sucked into the low-pressure chamber (C1-Lp) through the first suction port pipe (14-1).

[0125] When the drive shaft (53) rotates one revolution, and returns to the state illustrated in FIG. 3(B), the suction of refrigerant into the low-pressure chamber (C1-Lp) is completed. Then, the low-pressure chamber (C1-Lp) is changed into the high-pressure chamber (intermediate-pressure chamber) (C1-Hp) in which refrigerant is compressed, and another low-pressure chamber (C1-Lp) is formed across the first blade (23). When further rotating the drive shaft (53), the suction of refrigerant is repeated in the low-pressure chamber (C1-Lp). Meanwhile, the volume of the high-pressure chamber (intermediate-pressure chamber) (C1-Hp) is decreased, thereby compressing refrigerant in the high-pressure chamber (intermediate-pressure chamber) (C1-Hp). When a pressure in the high-pressure chamber (intermediate-pressure chamber) (C1-Hp) reaches a predetermined value, and a pressure difference between the high-pressure chamber (intermediate-pressure chamber) (C1-Hp) and the intermediate discharge space (17b) reaches a set value, the discharge valve is opened by intermediate-pressure refrigerant of the high-pressure chamber (intermediate-pressure chamber) (C1-Hp). Then, the intermediate-pressure refrigerant is discharged from the casing (10) through the first discharge port pipe (15-1) after passing through the intermediate discharge space (17b).

[0126] In the first inner cylinder chamber (C2), the volume of the low-pressure chamber (C2-Lp) is substantially minimum in the state illustrated in FIG. 3(F). Starting from such a state, the volume of the low-pressure chamber (C2-Lp) is increased as the state illustrated in FIG. 3(G) is changed to the state illustrated in FIG. 3(E) by rotating the drive shaft (53) clockwise as viewed in the figure. Then, refrigerant is sucked into the low-pressure chamber (C2-Lp) of the first inner cylinder chamber (C2) through the first suction port pipe (14-1) and the first injection path (42a).

[0127] When the drive shaft (53) rotates one revolution, and returns to the state illustrated in FIG. 3(F), the suction of refrigerant into the low-pressure chamber (C2-Lp) is completed. Then, the low-pressure chamber (C2-Lp) is changed into the high-pressure chamber (intermediate-pressure chamber) (C2-Hp) in which refrigerant is compressed, and another low-pressure chamber (C2-Lp) is formed across the first blade (23). When further rotating the drive shaft (53), the suction of refrigerant is repeated in the low-pressure chamber (C2-Lp). Meanwhile, the volume of the high-pressure chamber (intermediate-pressure chamber) (C2-Hp) is decreased, thereby compressing refrigerant in the high-pressure chamber (intermediate-pressure chamber) (C2-Hp). When a pressure in the high-pressure chamber (intermediate-pressure chamber) (C2-Hp) reaches a predetermined value, and a pressure difference between the high-pressure chamber (intermediate-pressure chamber) (C2-Hp) and the intermediate discharge space (17b) reaches a set value, the discharge valve is opened by intermediate-pressure refrigerant of the high-pressure chamber (intermediate-pressure chamber) (C2-Hp). Then, the intermediate-pressure refrigerant is discharged from the casing (10) through the first discharge port pipe (15-1) after passing through the intermediate discharge space (17b).

[0128] In the first outer cylinder chamber (C1), the discharge of refrigerant is started at a timing at which the compression mechanism is substantially in the state illustrated in FIG. 3(E). In the first inner cylinder chamber (C2), the discharge is started at a timing at which the compression mechanism is substantially in the state illustrated in FIG. 3(A). That is, the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2) are different from each other in the discharge timing by about 180°.

[0129] In the second compression mechanism (30), the rotation of the rotor (52) is transmitted to the second circular piston (32) through the drive shaft (53). Then, the second swing bush (37) reciprocates (moves back and forth) along the second blade (33), and the second circular piston (32) and the second swing bush (37) together swing relative to the second blade (33). In such a state, the second swing bush (37) is in substantial surface contact with the second circular piston (32) and the second blade (33). The second circular piston (32) revolves while swinging relative to the second outer cylinder section (31 a) and the second inner cylinder section (31b). Thus, the second compression mechanism (30) carries out a predetermined compression process.

[0130] The compression process is the substantially same as that of the first compression mechanism (20), except that a pressure is different. Refrigerant is compressed in the cylinder chambers (C3, C4). In the second inner cylinder chamber (C4) and the second outer cylinder chamber (C3), when a pressure in high-pressure chambers (C3-Hp, C4-Hp) reach a predetermined value, the discharge valve is opened by a refrigerant pressure, and refrigerant flows out from the compression chambers through the outlets (45b, 46b) of the front head (16) and the discharge valve. Refrigerant in the second outer cylinder chamber (C3) flows out from the casing (10) through the second discharge port a-pipe (15-2a), and refrigerant in the second inner cylinder chamber (C4) flows out from the casing through the second discharge port b-pipe (15-2b) after filling the casing (10).

<Operation of Air Conditioning Apparatus>

[0131] The air conditioning apparatus is switchable between the first operational state illustrated in FIG. 4 and the second operational state illustrated in FIG. 5 depending on the change in operational conditions. Note that the operation which will be described below is assumed as a cooling operation.

[0132] In the first operational state illustrated in FIG. 4, the first three-way valve (7a) is set to the first position, and the second three-way valve (7b) is set to the second position. When starting the compressor in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port pipe (14-1) of the compressor. Then, such refrigerant is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure refrigerant joins refrigerant from the gas-liquid separator (4), and flows into the branched pipe (68).

[0133] The intermediate-pressure refrigerant flowing through the branched pipe (68) branches into the second suction pipe (62a) and the second suction pipe (62b), and is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) of the second compression mechanism (30). The intermediate-pressure refrigerant sucked into the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). A part of the high-pressure refrigerant, which flows out from the second outer cylinder chamber (C3) is discharged through the second discharge port a-pipe (15-2a). The remaining refrigerant flowing out from the second inner cylinder chamber (C4) is discharged through the second discharge port b-pipe (15-2b) after filling the casing (10). The refrigerant discharged through the second discharge port a-pipe (15-2a) and the refrigerant discharged through the second discharge port b-pipe (15-2b) join together and flow into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (5), and flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the liquid refrigerant is decreased to a low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0134] In the second operational state illustrated in FIG. 5, the first three-way valve (7a) is set to the second position, and the second three-way valve (7b) is set to the first position. When starting the compressor in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port pipe (14-1). Then, such refrigerant is compressed into intermediate-pressure refrigerant (such a pressure is referred to as a "first intermediate pressure") in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The first intermediate-pressure refrigerant joins refrigerant from the gas-liquid separator (4), and then flows into the branched pipe (68).

[0135] The first intermediate-pressure refrigerant flowing through the branched pipe (68) is sucked into the second outer cylinder chamber (C3) of the second compression mechanism (30) through the second suction pipe (62a). The pressure of the first intermediate-pressure refrigerant sucked into the second outer cylinder chamber (C3) of the second compression mechanism (30) is increased in the second outer cylinder chamber (C3) (such a pressure is referred to as a "second intermediate pressure"). The refrigerant, the pressure of which is increased to the second intermediate pressure is discharged through the second discharge port a-pipe (15-2a). The refrigerant flowing out through the second discharge port a-pipe (15-2a) passes through the first three-way valve (7a) and the second three-way valve (7b), and then is sucked into the second inner cylinder chamber (C4) of the second compression mechanism (30) through the second suction port b-pipe (14-2b). In the second inner cylinder chamber (C4), the refrigerant is further compressed so as to have a high pressure, and is discharged to a high-pressure space inside the casing (10). The high-pressure refrigerant filling the casing (10) is discharged through the second discharge port b-pipe (15-2b), and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to the first intermediate pressure by the first expansion valve (5), and flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

Advantages of First Embodiments

[0136] According to the first embodiment, the suction volume of the first compression mechanism (20) is the same in the first and second operational states. However, in the first operational state, intermediate-pressure refrigerant is sucked into both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). On the other hand, in the second operational state, intermediate-pressure refrigerant is only sucked into the second outer cylinder chamber (C3). That is, the suction volume at the low-pressure stage is the same in the first and second operational states, whereas the suction volume at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0137] As in such a case, in the present embodiment, it is switchable between the first operational state in which the two cylinder chambers (C3, C4) of the second compression mechanism (30) are used in parallel, and the second operational state in which the cylinder chambers (C3, C4) are used in series. Thus, in the compressor (1) in which the two compression mechanisms (20, 30) are mechanically connected to the single shaft (53), the ratio of the suction volume of the low-pressure compression mechanism (20) to the suction volume of the high-pressure compression mechanism (30) in the first and second operational states can be adjusted. In such a manner, the ratio of the suction volume of the low-pressure compression mechanism (20) to the suction volume of the high-pressure compression mechanism (30) in the compressor (1) is adjusted depending on the operational conditions, thereby allowing an operation with high COP (coefficient of performance). In addition; a torque variation due to the compression of refrigerant can be adjusted.

[0138] For example, a case is considered, where the suction volume ratio is adjusted by unloading the low-pressure or high-pressure compression mechanism in the two-stage compression mechanism. However, unlike such an example, refrigerant is not compressed in the middle of a compression stroke in the present embodiment, thereby realizing a smooth operation.

Variation of First Embodiment

[0139] FIGS. 6-10 illustrate examples of switching patterns when switching (changing) the four cylinder chambers (C1, C2, C3, C4) of the first compression mechanism (20) and the second compression mechanism (30) between a connection in series and a connection in parallel. Each of the foregoing figures is a cross-sectional view of a main section.

[0140] In such examples, the first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into the first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into the first inner cylinder chamber (C2). The first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). The second suction port pipe (14-2) includes the second suction port a-pipe (14-2a) through which refrigerant is sucked into the second outer cylinder chamber (C3), and the second suction port b-pipe (14-2b) through which refrigerant is sucked into the second inner cylinder chamber (C4). The second discharge port pipe (15-2) includes the second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and the second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0141] In the example illustrated in FIG. 6, low-pressure refrigerant (LP) is sucked to the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a), and first intermediate-pressure refrigerant (IP1) is discharged through the first discharge port a-pipe (15-1a). The first intermediate-pressure refrigerant (IP1) is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) through the second suction port a-pipe (14-2a) and the second suction port b-pipe (14-2b), and is compressed to the second intermediate pressure. Then, such refrigerant is discharged through the second discharge port a-pipe (15-2a) and the second discharge port b-pipe (15-2b). The second intermediate-pressure refrigerant (IP2) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b). Such refrigerant is compressed into high-pressure refrigerant (HP), and is discharged through the first discharge port b-pipe (15-1b).

[0142] In the example illustrated in FIG. 7, low-pressure refrigerant (LP) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b), and is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). The pressure of the refrigerant is increased to the first intermediate pressure in the first inner cylinder chamber (C2) and the second outer cylinder chamber (C3), and the first intermediate-pressure refrigerant (IP1) is discharged through the first discharge port b-pipe (15-1b) and the second discharge port a-pipe (15-2a). The first intermediate-pressure refrigerant (IP1) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a). Then, the pressure of the refrigerant is increased to the second intermediate pressure, and is discharged through the first discharge port a-pipe (15-1a). The second intermediate-pressure refrigerant (IP2) is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). Such refrigerant is compressed into high-pressure refrigerant (HP), and is discharged through the second discharge port b-pipe (15-2b).

[0143] In the example illustrated in FIG. 8, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a). Then, the pressure of the refrigerant is increased to the first intermediate pressure, and is discharged through the first discharge port a-pipe (15-1a). The first intermediate-pressure refrigerant (IP1) is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). Then, the pressure of the refrigerant is increased to the second intermediate pressure, and such refrigerant is discharged through the second discharge port a-pipe (15-2a). The second intermediate-pressure refrigerant (IP2) is sucked into the first inner cylinder chamber (C2) through the second suction port b-pipe (14-2b). Then, the pressure of the refrigerant is increased to a third intermediate pressure, and such refrigerant is discharged through the first discharge port b-pipe (15-1b). The third intermediate-pressure refrigerant (IP3) is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). Such refrigerant is compressed into high-pressure refrigerant (HP), and is discharged through the second discharge port b-pipe (15-2b).

[0144] In the example illustrated in FIG. 9, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a), and is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). The pressure of the refrigerant is increased to the first intermediate pressure in the first outer cylinder chamber (C1) and the second inner cylinder chamber (C4), and the first intermediate-pressure refrigerant (IP1) is discharged through the first discharge port a-pipe (15-1a) and the second discharge port b-pipe (15-2b). The first intermediate-pressure refrigerant (IP1) is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). Then, the pressure of the refrigerant is increased to the second intermediate pressure, and such refrigerant is discharged through the second discharge port a-pipe (15-2a). The second intermediate-pressure refrigerant (IP2) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b). Such refrigerant is compressed into high-pressure refrigerant (HP), and is discharged through the first discharge port b-pipe (15-1b).

[0145] In the example illustrated in FIG. 10, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a), and is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). The pressure of the refrigerant is increased to the first intermediate pressure in the first outer cylinder chamber (C1) and the second outer cylinder chamber (C3), and the first intermediate-pressure refrigerant (IP1) is discharged through the first discharge port a-pipe (15-1a) and the second discharge port a-pipe (15-2a). The first intermediate-pressure refrigerant (IP1) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b). Then, the pressure of the refrigerant is increased to the second intermediate pressure, and such refrigerant is discharged through the first discharge port b-pipe (15-1b). The second intermediate-pressure refrigerant (IP2) is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). Such refrigerant is compressed into high-pressure refrigerant (HP), and is discharged through the second discharge port b-pipe (15-2b).

[0146] Even if the refrigerant circuit is configured so that the operational patterns of the examples illustrated in FIGS. 6-10 are switched as necessary, the four cylinder chambers (C1, C2, C3, C4) are switchable so that some of the four cylinder chambers (C1, C2, C3, C4) are used in series, and the remaining cylinder chambers (C1, C2, C3, C4) are used in parallel, thereby adjusting the volume ratio of the cylinder chambers. Thus, the operation with optimum COP is allowed depending on the operational conditions.

[0147] In addition, the combination of the low-pressure and high-pressure compression mechanisms may be freely changed, and it is not necessary that, e.g., the low-pressure compression mechanism is limited to the lower cylinder.

<<Second Embodiment of the Invention>>

[0148] A second embodiment of the present invention will be described with reference to FIGS. 11 and 12.

[0149] In a compressor of the second embodiment, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3) by way of a space inside a casing (10), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0150] Other configurations of the compressor (1) are basically the same as those of the first embodiment.

[0151] Next, a refrigerant circuit (60) will be described. Components of the refrigerant circuit (60) are the same as those of the first embodiment.

[0152] The first suction port pipe (14-1) of the compressor (1) is connected to a gas-side end of an evaporator (3) through a first suction pipe (61). The first discharge port pipe (15-1) of the compressor (1) is connected to a refrigerant gas outlet (4a) of a gas-liquid separator (4) through a first discharge pipe (63). An outlet (4c) of the gas-liquid separator (4) is connected to a liquid-side end of the evaporator (3) through a liquid pipe (66) including a second expansion valve (6) in the middle thereof.

[0153] The first discharge pipe (63) branches into a first branched pipe (68a) in the middle thereof, and further branches into a second branched pipe (68b). The first branched pipe (68a) is connected to the second suction port a-pipe (14-2a) of a second compression mechanism (30) through a second suction pipe (62a) including a muffler (9). The second branched pipe (68b) is connected to a second port (P2) of a second three-way valve (switching valve) (7b), and a first port (P1) of the second three-way valve (7b) is connected to the second suction port b-pipe (14-2b) of the second compression mechanism (30) through a second suction pipe (62b) including a muffler (9). A third port (P3) of the second three-way valve (7b) is connected to the first suction pipe (61) between the gas-side end of the evaporator (3) and the first suction port pipe (14-1) through a connecting pipe (67b).

[0154] One end of a second discharge pipe (64a) is connected to the second discharge port a-pipe (15-2a) of the second compression mechanism (30), and the other end of the second discharge pipe (64a) is connected to an inlet (4b) of the gas-liquid separator (4). In the middle of the second discharge pipe (64a), a gas cooler (2) and a first expansion valve (5) are provided in this order from the second discharge port a-pipe (15-2a) side.

[0155] The second discharge port b-pipe (15-2b) of the second compression mechanism (30) is connected to a first port (P1) of a first three-way valve (switching valve) (7a) through a second discharge pipe (64b). A second port (P2) of the first three-way valve (7a) is connected to a high-pressure injection pipe (18) provided so as to penetrate a body section of the casing (10), through a connecting pipe (67c). A third port (P3) of the first three-way valve (7a) is connected to the first discharge pipe (63) between the first discharge port pipe (15-1) and the first branched pipe (68a) through a connecting pipe (67d).

[0156] The three-way valve (7) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other, and a second position in which the first port (P1) and the third port (P3) are communicated with each other.

[0157] The three-way valve (7) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into the compression mechanism (20, 30). The three-way valve (7) is configured so that, by changing a combination of the four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (60), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0158] The switching mechanism (7) is switchable between a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism; and a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) and one of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C3, C4) of the second compression mechanism (30) is used as the high-pressure compression mechanism.

[0159] The switching mechanism (volume ratio changing unit) (7) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0160] In a refrigerating apparatus, it is switchable between a first operational state illustrated in FIG. 11 and a second operational state illustrated in FIG. 12 depending on the change in operational conditions.

[0161] In the first operational state illustrated in FIG. 11, the first three-way valve (7a) and the second three-way valve (7b) are set to the first position. When starting the compressor in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port pipe (14-1) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure refrigerant joins refrigerant from the gas-liquid separator (4); and flows into the first branched pipe (68a) and the second branched pipe (68b).

[0162] The intermediate-pressure refrigerant flowing through the first branched pipe (68a) is sucked into the second outer cylinder chamber (C3) of the second compression mechanism (30) through the second suction pipe (62a), and the intermediate-pressure refrigerant flowing through the second branched pipe (68b) is sucked into the second inner cylinder chamber (C4) of the second compression mechanism (30) through the second suction pipe (62b). The intermediate-pressure refrigerant sucked into the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). The high-pressure refrigerant flows out from the second inner cylinder chamber (C4) through the second discharge port b-pipe (15-2b), and flows into the casing (10) through the connecting pipe (67c). In addition, the refrigerant flowing out from the second outer cylinder chamber (C3) is also discharged to the casing (10). That is, the casing (10) is filled with the high-pressure refrigerant.

[0163] The high-pressure refrigerant filling the casing (10) is discharged through the second discharge port a-pipe (15-2a). The refrigerant discharged through the second discharge port a-pipe (15-2a) flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to a low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0164] In the second operational state illustrated in FIG. 12, the first three-way valve (7a) and the second three-way valve (7b) are set to the second position. When starting the compressor (1) in such a state, a part of low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port pipe (14-1) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The remaining low-pressure gas refrigerant is sucked into the second inner cylinder chamber (C4) of the second compression mechanism (30) through the second three-way valve (7b) and the second suction port b-pipe (14-2b), and is changed into intermediate-pressure refrigerant in the second inner cylinder chamber (C4).

[0165] The intermediate-pressure refrigerant discharged from the first compression mechanism (20) and the intermediate-pressure refrigerant discharged from the second inner cylinder chamber (C4) of the second compression mechanism (30) join together. Then, such refrigerant further joins refrigerant from the gas-liquid separator (4), and flows into the first branched pipe (68a).

[0166] The intermediate-pressure refrigerant flowing through the first branched pipe (68a) is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a) of the second compression mechanism (30). The refrigerant sucked into the second outer cylinder chamber (C3) of the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3). The high-pressure refrigerant flows out from the second outer cylinder chamber (C3) to the space inside the casing (10), and fills such a space. The high-pressure refrigerant is discharged through the second discharge port a-pipe (15-2a), and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to the low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

Advantages of Second Embodiment

[0167] According to the second embodiment, the suction volume of low-pressure refrigerant in the second operational state is larger than the suction volume of low-pressure refrigerant in the first operational state. In addition, the suction volume of intermediate-pressure refrigerant in the second operational state is smaller than the suction volume of intermediate-pressure refrigerant in the first operational state.

[0168] That is, in the first and second operational states, a suction amount at the low-pressure stage is larger in the second operational state than in the first operational state, whereas a suction amount at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0169] As described above, in the present embodiment, the cylinder chambers of the second compression mechanism (30) are used while changing their combination with other cylinder chambers between the first and second operational states. Thus, in the compressor (1) in which the two compression mechanisms (20, 30) are mechanically connected to a single shaft (53), the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Thus, the suction volume ratio of the compressor is adjusted depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

Variation of Second Embodiment

[0170] FIGS. 13-21 illustrate examples of switching patterns when changing a combination of the four cylinder chambers of the first compression mechanism (20) and the second compression mechanism (30). Each of the foregoing figures is a cross-sectional view of a main section.

[0171] In such examples, the first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into the first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into the first inner cylinder chamber (C2). The first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). The second suction port pipe (14-2) includes the second suction port a-pipe (14-2a) through which refrigerant is sucked into the second outer cylinder chamber (C3), and the second suction port b-pipe (14-2b) through which refrigerant is sucked into the second inner cylinder chamber (C4). The second discharge port pipe (15-2) includes the second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and the second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0172] In the example illustrated in FIG. 13, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2) through the first suction port a-pipe (14-1a) and the first suction port b-pipe (14-1b), and is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port a-pipe (15-1a), the first discharge port b-pipe (15-1b), and the second discharge port a-pipe (15-2a), and is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). The intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP) in the second inner cylinder chamber (C4), and is discharged through the second discharge port b-pipe (15-2b).

[0173] In the example illustrated in FIG. 14, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to a first intermediate pressure. The first intermediate-pressure refrigerant (IP) is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) through the second suction port a-pipe (14-2a) and the second suction port b-pipe (14-2b). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to a second intermediate pressure. The second intermediate-pressure refrigerant (IP) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b), and is compressed into high-pressure refrigerant (HP). Then, such refrigerant is discharged through the first discharge port b-pipe (15-1b).

[0174] In the example illustrated in FIG. 15, low-pressure refrigerant (LP) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b), and is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port b-pipe (15-1b) and the second discharge port a-pipe (15-2a). The intermediate-pressure refrigerant (IP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a), and is sucked into the second outer cylinder chamber (C3) through the second suction port b-pipe (14-2b). In the first outer cylinder chamber (C1) and the second inner cylinder chamber (C4), the intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP). The high-pressure refrigerant (HP) is discharged through the first discharge port a-pipe (15-1a) and the second discharge port b-pipe (15-2b).

[0175] In the example illustrated in FIG. 16, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2) through the first suction port a-pipe (14-1a) and the first suction port b-pipe (14-1b), and is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port a-pipe (15-1a), the first discharge port b-pipe (15-1b), and the second discharge port b-pipe (15-2b), and is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). The intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP) in the second outer cylinder chamber (C3), and is discharged through the second discharge port a-pipe (15-2a).

[0176] In the example illustrated in FIG. 17, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port a-pipe (15-1a). Such refrigerant is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b), into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a), and into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). The intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP) in the first inner cylinder chamber (C2), the second outer cylinder chamber (C3), and the second inner cylinder chamber (C4). The high-pressure refrigerant (HP) is discharged through the first discharge port b-pipe (15-1b), the second discharge port a-pipe (15-2a), and the second discharge port b-pipe (15-2b).

[0177] In the example illustrated in FIG. 18, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a), and is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port a-pipe (15-1a) and the second discharge port b-pipe (15-2b). Such refrigerant is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b), and into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). The intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP) in the first inner cylinder chamber (C2) and the second outer cylinder chamber (C3). The high-pressure refrigerant (HP) is discharged through the first discharge port b-pipe (15-1b) and the second discharge port a-pipe (15-2a).

[0178] In the example illustrated in FIG. 19, low-pressure refrigerant (LP) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b), and is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) through the second suction port a-pipe (14-2a) and the second suction port b-pipe (14-2b). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port b-pipe (15-1b), the second discharge port a-pipe (15-2a), and the second discharge port b-pipe (15-2b), and is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a). The intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP) in the first outer cylinder chamber (C1), and is discharged through the first discharge port a-pipe (15-1a).

[0179] In the example illustrated in FIG. 20, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a), and is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port a-pipe (15-1a) and the first discharge port b-pipe (15-1b). The intermediate-pressure refrigerant (IP) is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a), and is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). The intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP) in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4), and is discharged through the second discharge port a-pipe (15-2a) and the second discharge port b-pipe (15-2b).

[0180] In the example illustrated in FIG. 21, low-pressure refrigerant (LP) is sucked into the first outer cylinder chamber (C1) through the first suction port a-pipe (14-1a), and is sucked into the second outer cylinder chamber (C3) through the second suction port a-pipe (14-2a). Then, such refrigerant is compressed, and therefore the pressure of the refrigerant is increased to the intermediate pressure level. The intermediate-pressure refrigerant (IP) is discharged through the first discharge port a-pipe (15-1a) and the second discharge port a-pipe (15-2a). The intermediate-pressure refrigerant (IP) is sucked into the first inner cylinder chamber (C2) through the first suction port b-pipe (14-1b), and is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b). The intermediate-pressure refrigerant (IP) is compressed into high-pressure refrigerant (HP) in the first inner cylinder chamber (C2) and the second inner cylinder chamber (C4), and is discharged through the first discharge port b-pipe (15-1b) and the second discharge port b-pipe (15-2b).

[0181] Even if the refrigerant circuit is configured so that the examples illustrated in FIGS. 13-21 are combined as necessary to switch the operational state, the combination of the four cylinder chambers is changed, thereby changing the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism. Thus, the operation with optimum COP is allowed depending on the operational conditions.

<<Third Embodiment of the Invention>>

[0182] A third embodiment of the present invention will be described with reference to FIGS. 22 and 23.

[0183] In a compressor (1) of the third embodiment, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4) by way of a space inside a casing (10).

[0184] Other configurations of the compressor (1) are basically the same as those of the first embodiment.

[0185] Next, a refrigerant circuit (60) will be described. Components of the refrigerant circuit (60) are the same as those of the first embodiment.

[0186] The first suction port a-pipe (14-1a) of the compressor (1) is connected to a gas-side end of an evaporator (3) through a first suction pipe (61 a). The first discharge port a-pipe (15-1a) of the compressor (1) is connected to a refrigerant gas outlet (4a) of a gas-liquid separator (4) through a first discharge pipe (63a). An outlet (4c) of the gas-liquid separator (4) is connected to a liquid-side end of the evaporator (3) through a liquid pipe (66) including a second expansion valve (6) in the middle thereof.

[0187] The first discharge pipe (63a) branches into a first branched pipe (68a) and a second branched pipe (68b). The second branched pipe (68b) includes a muffler

(9), and is connected to the second suction port b-pipe (14-2b) of a second compression mechanism (30) through a second suction pipe (62b). The first branched pipe (68a) is connected to a first port (P1) of a second four-way valve (switching valve) (8b). A second port (P2) of the second four-way valve (8b) is connected to one end of a second suction pipe (62a) including a muffler (9), and the other end of the second suction pipe (62a) is connected to the second suction port a-pipe (14-2a) of the second compression mechanism (30). A third port (P3) of the second four-way valve (8b) is connected to the first suction pipe (61a) between the gas-side end of the evaporator (3) and a muffler (9). A fourth port (P4) of the second four-way valve (8b) is connected to one end of a first suction pipe (61b) including a muffler (9), and the other end of the first suction pipe (61 b) is connected to the first suction port b-pipe (14-1b).

[0188] One end of a first discharge pipe (63b) is connected to the first discharge port b-pipe (15-1b), and the other end of the first discharge pipe (63b) is connected to a first port (P1) of a first four-way valve (switching valve) (8a). One end of a connecting pipe (67e) is connected to a second port (P2) of the first four-way valve (8a), and the other end of the connecting pipe (67e) is connected to the first discharge pipe (63a) between the first discharge port pipe (15-1) and the first branched pipe (68a).

[0189] The second discharge port a-pipe (15-2a) is connected to a third port (P3) of the first four-way valve (8a) through a second discharge pipe (64a). One end of a second discharge pipe (64b) is connected to the second discharge port b-pipe (15-2b), and the other end of the second discharge pipe (64b) is connected to an inlet (4b) of the gas-liquid separator (4). In the middle of the second discharge pipe (64b), a gas cooler (2) and a first expansion valve (5) are provided in this order from the second discharge port b-pipe (15-2b) side. A fourth port (P4) of the first four-way valve (8a) is connected to the second discharge pipe (64b) between the second discharge port b-pipe (15-2b) and the gas cooler (2) through a connecting pipe (67f).

[0190] Each of the four-way valves (8a, 8b) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other, and the third port (P3) and the fourth port (P4) are communicated with each other (see FIG. 22); and a second position in which the first port (P1) and the fourth port (P4) are communicated with each other, and the second port (P2) and the third port (P3) are communicated with each other (see FIG. 23).

[0191] The four-way valve (8a, 8b) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into the compression mechanism (20, 30). The four-way valve (8a, 8b) is configured so that, by changing a combination of the four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (60), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0192] The switching mechanism (8a, 8b) is switchable between a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism; and a state in which one of the cylinder chambers (C1, C2) of the first compression mechanism (20) and one of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C1, C2) of the first compression mechanism (20) and the other cylinder chamber (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism.

[0193] The switching mechanism (volume ratio changing unit) (8a, 8b) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0194] In a refrigerating apparatus, it is switchable between a first operational state illustrated in FIG. 22 and a second operational state illustrated in FIG. 23 depending on the change in operational conditions.

[0195] In the first operational state illustrated in FIG. 22, the first four-way valve (8a) and the second four-way valve (8b) are set to the first position. When starting the compressor (1) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port a-pipe (14-1a) and the first suction port b-pipe (14-1b) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure refrigerant flows while joining refrigerant from other direction through the first four-way valve (8a). Such refrigerant further joins refrigerant from the gas-liquid separator (4), and flows into the first branched pipe (68a) and the second branched pipe (68b).

[0196] After passing through the second four-way valve (8b), the intermediate-pressure refrigerant flowing through the first branched pipe (68a) is sucked into the second outer cylinder chamber (C3) of the second compression mechanism (30) through the second suction pipe (62a), and the intermediate-pressure refrigerant flowing through the second branched pipe (68b) is sucked into the second inner cylinder chamber (C4) of the second compression mechanism (30) through the second suction pipe (62b). The intermediate-pressure refrigerant sucked into the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). In the second outer cylinder chamber (C3), the high-pressure refrigerant flows out through the second discharge port a-pipe (15-2a), and flows into the connecting pipe (67f) through the first four-way valve (8a). Meanwhile, the high-pressure refrigerant flowing out from the second inner cylinder chamber (C4) is discharged into the casing (10), and fills the casing (10). Then, such refrigerant is discharged through the second discharge port b-pipe (15-2b). The high-pressure refrigerant through the second discharge port a-pipe (15-2a) and the high-pressure refrigerant through the second discharge port b-pipe (15-2b) join together, and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to a low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0197] In the second operational state illustrated in FIG. 23, the first four-way valve (8a) and the second four-way valve (8b) are set to the second position. When starting the compressor (1) in such a state, a part of low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port a-pipe (14-1a) of the compressor (1), and the remaining refrigerant is sucked into the second compression mechanism (30) through the second suction port a-pipe (14-2a). Such refrigerant is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the second outer cylinder chamber (C3).

[0198] The intermediate-pressure refrigerant discharged from the first outer cylinder chamber (C1) of the first compression mechanism (20) and the intermediate-pressure refrigerant discharged from the second outer cylinder chamber (C3) of the second compression mechanism (30) flow while joining together through the first four-way valve (8a). Such refrigerant further joins refrigerant from the gas-liquid separator (4), and flows into the first branched pipe (68a) and the second branched pipe (68b).

[0199] The intermediate-pressure refrigerant flowing through the second branched pipe (68b) is sucked into the second inner cylinder chamber (C4) through the second suction port b-pipe (14-2b) of the second compression mechanism (30). The refrigerant sucked into the second inner cylinder chamber (C4) of the second compression mechanism (30) is compressed into high-pressure refrigerant in the second inner cylinder chamber (C4). The high-pressure refrigerant flows out from the second inner cylinder chamber (C4) to the space inside the casing (10), and fills such a space. Then, such refrigerant is discharged through the second discharge port b-pipe (15-2b).

[0200] Meanwhile, the intermediate-pressure refrigerant flowing through the first branched pipe (68a) is sucked into the first inner cylinder chamber (C2) of the first compression mechanism (20) through second four-way valve (8b) and the first suction port b-pipe (14-1b). In the first inner cylinder chamber (C2), the refrigerant is compressed into high-pressure refrigerant. The high-pressure refrigerant flows out from the first inner cylinder chamber (C2) to outside the casing (10) through the first discharge port b-pipe (15-1b). The high-pressure refrigerant discharged through the first discharge port b-pipe (15-1b) joins the high-pressure refrigerant discharged through the second discharge port b-pipe (15-2b), and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to the low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

Advantages of Third Embodiment

[0201] According to the third embodiment, the outer cylinder chambers (C1, C3) are larger than the inner cylinder chambers (C2, C4), and therefore the suction volume of low-pressure refrigerant in the second operational state is larger than the suction volume of low-pressure refrigerant in the first operational state. In addition, the suction volume of intermediate-pressure refrigerant in the second operational state is smaller than the suction volume of intermediate-pressure refrigerant in the first operational state.

[0202] That is, in the first and second operational states, the suction volume at the low-pressure stage is larger in the second operational state than in the first operational state, whereas the suction volume at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0203] As described above, in the present embodiment, the cylinder chambers (C1, C2, C3. C4) of the first compression mechanism (20) and the second compression mechanism (30) are used while changing their combination between the first and second operational states. Thus, in the compressor (1) in which the two compression mechanisms (20, 30) are mechanically connected to a single shaft (53), the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Thus, the suction volume ratio of the compressor is adjusted depending on the operational conditions while performing an operation with high COP (coefficient of performance).

<<Fourth Embodiment of the Invention>>

[0204] A fourth embodiment of the present invention will be described with reference to FIGS. 24 and 25.

[0205] In a compressor (1) of the fourth embodiment, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3) by way of a space inside a casing (10), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0206] Other configurations of the compressor (1) are basically the same as those of the first embodiment.

[0207] Next, a refrigerant circuit (60) will be described. Components of the refrigerant circuit (60) are the same as those of the first embodiment.

[0208] The first suction port pipe (14-1) of the compressor (1) is connected to a gas-side end of an evaporator (3) through a first suction pipe (61). The first discharge port pipe (15-1) of the compressor (1) is connected to a refrigerant gas outlet (4a) of a gas-liquid separator (4) through a first discharge pipe (63). An outlet (4c) of the gas-liquid separator (4) is connected to a liquid-side end of the evaporator (3) through a liquid pipe (66) including a second expansion valve (6) in the middle thereof.

[0209] The first discharge pipe (63) branches into a branched pipe (68) in the middle thereof. The branched pipe (68) is connected to the second suction port pipe (14-2) of a second compression mechanism (30) through a second suction pipe (62).

[0210] The second discharge port a-pipe (15-2a) of the second compression mechanism (30) is connected to one end of a second discharge pipe (64a), and the other end of the second discharge pipe (64a) is connected to an inlet (4b) of the gas-liquid separator (4). In the middle of the second discharge pipe (64a), a gas cooler (2) and a first expansion valve (5) are provided in this order from the second discharge port a-pipe (15-2a) side.

[0211] The second discharge port b-pipe (15-2b) of the second compression mechanism (30) is connected to a first port (P1) of a three-way valve (7) through a second discharge pipe (64b). A second port (P2) of the three-way valve (7) is connected to a high-pressure injection pipe (18) provided so as to penetrate a body section of the casing (10), through a connecting pipe (67c). A third port (P3) of the three-way valve (7) is connected to the first discharge pipe (63) between the first discharge port pipe (15-1) and a first branched pipe (68a) through a connecting pipe (67d).

[0212] The three-way valve (7) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other, and a second position in which the first port (P1) and the third port (P3) are communicated with each other.

[0213] The three-way valve (7) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into the compression mechanism (20, 30). The three-way valve (7) is configured so that, by changing a combination of the four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (60), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0214] When the first compression mechanism (20) is at the low-pressure stage and the second compression mechanism (30) is at the high-pressure stage, the three-way valve (7) is switchable between a state in which refrigerant is compressed in both of the cylinder chambers (C3, C4) of the second compression mechanism (30) to provide a difference between a suction pressure and a discharge pressure; and a state in which refrigerant is compressed in one of the cylinder chambers (outer cylinder chamber) (C3, C4) of the second compression mechanism (30) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other cylinder chamber (inner cylinder chamber) (C3, C4) allow uncompressed refrigerant to pass through the other cylinder chamber (C3, C4). That is, refrigerant can merely pass through the inner cylinder chamber (C4).

[0215] The switching mechanism (volume ratio changing unit) (7) changes the ratio of the suction volume of the low-pressure compression mechanism (20) to the suction volume of the high-pressure compression mechanism (30) depending on a change in operational conditions.

Operation

[0216] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 24 and a second operational state illustrated in FIG. 25 depending on the change in operational conditions.

[0217] In the first operational state illustrated in FIG. 24, the three-way valve (7) is set to the first position. When starting the compressor (1) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in an evaporator (3) is sucked into the first compression mechanism (20) through the first suction pipe (61) and the first suction port pipe (14-1) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure refrigerant joins refrigerant from the gas-liquid separator (4), and flows into the branched pipe (68).

[0218] The intermediate-pressure refrigerant flowing through the branched pipe (68) is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) of the second compression mechanism (30) through the second suction pipe (62) and the second suction port pipe (14-2). The intermediate-pressure refrigerant sucked into the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). On the second inner cylinder chamber (C4) side, the high-pressure refrigerant flows out through the second discharge port b-pipe (15-2b), and flows into the casing (10) through the connecting pipe (67c). The refrigerant flowing out from the second outer cylinder chamber (C3) is also discharged into the casing (10). That is, the casing (10) is filled with the high-pressure refrigerant.

[0219] The high-pressure refrigerant filling the casing (10) is discharged through the second discharge port a-pipe (15-2a). The refrigerant discharged through the second discharge port a-pipe (15-2a) flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to a low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0220] In the second operational state illustrated in FIG. 25, the three-way valve (7) is set to the second position. When starting the compressor (1) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction pipe (61) and the first suction port pipe (14-1) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure discharged from the first compression mechanism (20) joins refrigerant from the gas-liquid separator (4), and flows into the branched pipe (68).

[0221] The intermediate-pressure refrigerant flowing through the branched pipe (68) is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) through the second suction port pipe (14-2) of the second compression mechanism (30). The refrigerant sucked into the second outer cylinder chamber (C3) of the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3). The high-pressure refrigerant flows out from the second outer cylinder chamber (C3) to the space inside the casing (10), and fills such a space. The high-pressure refrigerant is discharged through the second discharge port a-pipe (15-2a), and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to the low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0222] Meanwhile, for the refrigerant sucked into the second inner cylinder chamber (C4) of the second compression mechanism (30), the three-way valve (7) is switched to the second position, and therefore the second discharge port b-pipe (15-2b) is communicated with the first discharge pipe (63). That is, the second discharge port b-pipe (15-2b) is under an intermediate pressure. Thus, the intermediate-pressure refrigerant sucked into the second inner cylinder chamber (C4) substantially flows out (merely pass) through the second discharge port b-pipe (15-2b) without being compressed. In such a manner, a cylinder volume (discharge volume) of the second compression mechanism (30) is smaller in the second operational state than in the first operational state.

Advantages of Fourth Embodiment

[0223] According to the fourth embodiment, the suction volume of low-pressure refrigerant in the first operational state is the same as the suction volume of low-pressure refrigerant in the second operational state. On the other hand, the suction volume of intermediate-pressure refrigerant in the second operational state is smaller than the suction volume of intermediate-pressure refrigerant in the first operational state.

[0224] That is, in the first and second operational states, the suction volume at the low-pressure stage is the same between the first and second operational states, and the suction volume at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0225] In the present embodiment, refrigerant merely passes through the inner cylinder chamber of the second compression mechanism (30) in the second operational state. Thus, in the compressor (1) in which the two compression mechanisms (20, 30) are mechanically connected to a single shaft (53), the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Thus, the suction volume ratio of the compressor is adjusted depending on the operational conditions while performing an operation with high COP (coefficient of performance).

<<Fifth Embodiment of the Invention>>

[0226] A fifth embodiment of the present invention will be described with reference to FIGS. 26 and 27.

[0227] In a compressor (1) of the fifth embodiment, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4) by way of a space inside a casing (10).

[0228] Other configurations of the compressor (1) are basically the same as those of the first embodiment.

[0229] Next, a refrigerant circuit (60) will be described. Components of the refrigerant circuit (60) are the same as those of the first embodiment.

[0230] The first suction port pipe (14-1) of the compressor (1) is connected to a gas-side end of an evaporator (3) through a first suction pipe (61). The first discharge port pipe (15-1) of the compressor (1) is connected to a refrigerant gas outlet (4a) of a gas-liquid separator (4) through a first discharge pipe (63). An outlet (4c) of the gas-liquid separator (4) is connected to a liquid-side end of the evaporator (3) through a liquid pipe (66) including a second expansion valve (6) in the middle thereof.

[0231] The first discharge pipe (63) branches into a branched pipe (68) in the middle thereof. The branched pipe (68) is connected to the second suction port pipe (14-2) of a second compression mechanism (30) through a second suction pipe (62).

[0232] The second discharge port b-pipe (15-2b) of the second compression mechanism (30) is connected to one end of a second discharge pipe (64b), and the other end of the second discharge pipe (64b) is connected to an inlet (4b) of the gas-liquid separator (4). In the middle of the second discharge pipe (64b), a gas cooler (2) and a first expansion valve (5) are provided in this order from the second discharge port b-pipe (15-2b) side.

[0233] The second discharge port a-pipe (15-2a) of the second compression mechanism (30) is connected to a first port (P1) of a three-way valve (7) through a second discharge pipe (64a). A second connecting pipe (67i) is connected to a second port (P2) of the three-way valve (7), and the second connecting pipe (67i) is connected to the second discharge pipe (64b) between the second discharge port b-pipe (15-2b) and the gas cooler (2). A first connecting pipe (67j) is connected to a third port (P3) of the three-way valve (7), and the first connecting pipe (67j) joins the first discharge pipe (63).

[0234] The three-way valve (7) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other, and a second position in which the first port (P1) and the third port (P3) are communicated with each other.

[0235] The three-way valve (7) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into the compression mechanism (20, 30). The three-way valve (7) is configured so that, by changing a combination of the four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (60), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0236] When the first compression mechanism (20) is at the low-pressure stage and the second compression mechanism (30) is at the high-pressure stage, the three-way valve (7) is switchable between a state in which refrigerant is compressed in both of the cylinder chambers (C3, C4) of the second compression mechanism (30) to provide a difference between a suction pressure and a discharge pressure; and a state in which refrigerant is compressed in one of the cylinder chambers (inner cylinder chamber) (C3, C4) of the second compression mechanism (30) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other cylinder chamber (outer cylinder chamber) (C3, C4) allow uncompressed refrigerant to pass through the other cylinder chamber (C3, C4). That is, refrigerant can merely pass through the outer cylinder chamber (C3).

[0237] The switching mechanism (volume ratio changing unit) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0238] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 26 and a second operational state illustrated in FIG. 27 depending on the change in operational conditions.

[0239] In the first operational state illustrated in FIG. 26, the three-way valve (7) is set to the first position. When starting the compressor (1) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction pipe (61) and the first suction port pipe (14-1) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure refrigerant joins refrigerant from the gas-liquid separator (4), and flows into the branched pipe (68).

[0240] The intermediate-pressure refrigerant flowing through the branched pipe (68) is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) of the second compression mechanism (30) through the second suction pipe (62) and the second suction port pipe (14-2). The intermediate-pressure refrigerant sucked into the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). On the second outer cylinder chamber (C3) side, the high-pressure refrigerant flows out through the second discharge port a-pipe (15-2a), and joins the second discharge pipe (64b) through the three-way valve (7) and the second connecting pipe (67i). On the second inner cylinder chamber (C4) side, the refrigerant is discharged from the casing (10) through the second discharge port b-pipe (15-2b).

[0241] The refrigerant discharged through the second discharge port b-pipe (15-2b) joins the refrigerant through the second discharge port a-pipe (15-2a), and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to a low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0242] In the second operational state illustrated in FIG. 27, the three-way valve (7) is set to the second position. When starting the compressor (1) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction pipe (61) and the first suction port pipe (14-1) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure refrigerant discharged from the first compression mechanism (20) joins refrigerant from the gas-liquid separator (4), and flows into the branched pipe (68).

[0243] The intermediate-pressure refrigerant flowing through the branched pipe (68) is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) through the second suction port pipe (14-2) of the second compression mechanism (30). The refrigerant sucked into the second inner cylinder chamber (C4) of the second compression mechanism (30) is compressed into high-pressure refrigerant in the second inner cylinder chamber (C4). The high-pressure refrigerant flows out from the second inner cylinder chamber (C4) to the space inside the casing (10), and fills such a space. The high-pressure refrigerant is discharged through the second discharge port b-pipe (15-2b), and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to the low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0244] Meanwhile, the three-way valve (7) is switched to the second position, and therefore the second discharge port a-pipe (15-2a) is communicated with the first discharge pipe (63). Thus, the refrigerant sucked into the second outer cylinder chamber (C3) of the second compression mechanism (30) is not compressed. That is, the second discharge port a-pipe (15-2a) is under an intermediate pressure. Thus, the intermediate-pressure refrigerant sucked into the second outer cylinder chamber (C3) substantially flows out (merely pass) through the second discharge port a-pipe (15-2a) without being compressed. In such a manner, a cylinder volume (discharge volume) of the second compression mechanism (30) is smaller in the second operational state than in the first operational state.

Advantages of Fifth Embodiment

[0245] According to the fifth embodiment, the suction volume of low-pressure refrigerant in the first operational state is the same as the suction volume of low-pressure refrigerant in the second operational state. On the other hand, the suction volume of intermediate-pressure refrigerant in the second operational state is smaller than the suction volume of intermediate-pressure refrigerant in the first operational state.

[0246] That is, in the first and second operational states, the suction volume at the low-pressure stage is the same between the first and second operational states, and the suction volume at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0247] In the present embodiment, refrigerant merely passes through the second outer cylinder chamber (C3) of the second compression mechanism (30) in the second operational state. Thus, in the compressor (1) in which the two compression mechanisms (20, 30) are mechanically connected to a single shaft (53), the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Consequently, the suction volume ratio of the compressor is adjusted depending on the operational conditions while performing an operation with high COP (coefficient of performance).

[0248] In the fifth embodiment, a configuration may be employed, in which refrigerant merely pass through the outer cylinder chamber of the first compression mechanism, thereby adjusting the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states.

<<Sixth Embodiment of the Invention>>

[0249] A sixth embodiment of the present invention will be described with reference to FIGS. 28 and 29.

[0250] In a compressor (1) of the sixth embodiment, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) by way of a space inside a casing (10).

[0251] Other configurations of the compressor (1) are basically the same as those of the first embodiment.

[0252] Next, a refrigerant circuit (60) will be described. Components of the refrigerant circuit (60) are the same as those of the first embodiment.

[0253] The first suction port a-pipe (14-1a) of the compressor (1) is connected to a gas-side end of an evaporator (3) through a first suction pipe (61a) including a muffler (9). One end of a first suction pipe (61b) is connected to the first suction port b-pipe (14-1b) of the compressor (1), and the other end of the first suction pipe (61 b) is connected to a first port (P1) of a three-way valve (7). A second port (P2) of the three-way valve (7) is connected to the first suction pipe (61 a) between the first suction port a-pipe (14-1a) and the muffler (9) through a connecting pipe (67g).

[0254] The first discharge port pipe (15-1) of the compressor (1) is connected to a refrigerant gas outlet (4a) of a gas-liquid separator (4) through a first discharge pipe (63). An outlet (4c) of the gas-liquid separator (4) is connected to a liquid-side end of the evaporator (3) through a liquid pipe (66) including a second expansion valve (6) in the middle thereof.

[0255] The first discharge pipe (63) branches into a branched pipe (68) in the middle thereof. The branched pipe (68) is connected to the second suction port pipe (14-2) of a second compression mechanism (30) through a second suction pipe (62). The branched pipe (68) further branches into a connecting pipe (67h) including a muffler (9), and the connecting pipe (67h) is connected to a third port (P3) of the three-way valve (7).

[0256] The second discharge port pipe (15-2) of the second compression mechanism (30) is connected to one end of a second discharge pipe (64), and the other end of the second discharge pipe (64) is connected to an inlet (4b) of the gas-liquid separator (4). In the middle of the second discharge pipe (64), a gas cooler (2) and a first expansion valve (5) are provided in this order from the second discharge port pipe (15-2) side.

[0257] The three-way valve (7) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other, and a second position in which the first port (P1) and the third port (P3) are communicated with each other.

[0258] The three-way valve (7) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into the compression mechanism (20, 30). The three-way valve (7) is configured so that, by changing a combination of the four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (60), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0259] When the first compression mechanism (20) is at the low-pressure stage and the second compression mechanism (30) is at the high-pressure stage, the switching mechanism is switchable between a state in which refrigerant is compressed in both of the cylinder chambers (C1, C2) of the first compression mechanism (20) to provide a difference between a suction pressure and a discharge pressure; and a state in which refrigerant is compressed in one of the cylinder chambers (C1, C2) of the first compression mechanism (20) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other cylinder chamber (C1, C2) allow uncompressed refrigerant to pass through the other cylinder chamber (C1, C2). That is, refrigerant can merely pass through the cylinder chamber (C2).

[0260] The switching mechanism (volume ratio changing unit) changes the ratio of the suction volume of the low-pressure compression mechanism (20) to the suction volume of the high-pressure compression mechanism (30) depending on a change in operational conditions.

Operation

[0261] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 28 and a second operational state illustrated in FIG. 29 depending on the change in operational conditions.

[0262] In the first operational state illustrated in FIG. 28, the three-way valve (7) is set to the first position. When starting the compressor (1) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port a-pipe (14-1a) and the first suction port b-pipe (14-1b) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). The intermediate-pressure refrigerant joins refrigerant from the gas-liquid separator (4), and flows into the branched pipe (68).

[0263] The intermediate-pressure refrigerant flowing through the branched pipe (68) is sucked into the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4) of the second compression mechanism (30) through the second suction port pipe (14-2). The intermediate-pressure refrigerant sucked into the second compression mechanism (30) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). The high-pressure refrigerant is discharged into the casing (10). That is, the casing (10) is filled with the high-pressure refrigerant.

[0264] The high-pressure refrigerant filling the casing (10) is discharged through the second discharge port pipe (15-2). The refrigerant discharged through the second discharge port pipe (15-2) flows into the gas cooler (2) through the second discharge pipe (64). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (5), and such refrigerant flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to a low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

[0265] In the second operational state illustrated in FIG. 29, the three-way valve (7) is set to the second position. When starting the compressor (1) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (3) is sucked into the first compression mechanism (20) through the first suction port a-pipe (14-1a) of the compressor (1), and is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1).

[0266] The intermediate-pressure refrigerant discharged from the first compression mechanism (20) joins refrigerant from the gas-liquid separator (4), and flows into the branched pipe (68).

[0267] The intermediate-pressure refrigerant flowing through the branched pipe (68) branches into the connecting pipe (67h), and is sucked into the first inner cylinder chamber (C2) of the first compression mechanism (20) through the first suction port b-pipe (14-1b). The first discharge port pipe (15-1) is under an intermediate pressure, and therefore refrigerant is not substantially compressed in the first inner cylinder chamber (C2).

[0268] Meanwhile, the refrigerant sucked into the second compression mechanism (30) through the branched pipe (68) is compressed into high-pressure refrigerant in the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4). The high-pressure refrigerant is discharged into the casing (10), and fills the casing (10). The high-pressure refrigerant in the casing (10) is discharged through the second discharge port pipe (15-2), and flows into the gas cooler (2). After the refrigerant dissipates heat to outdoor air in the gas cooler (2), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (5), and flows into the gas-liquid separator (4). The liquid refrigerant separated in the gas-liquid separator (4) flows out from the gas-liquid separator (4). After the pressure of the refrigerant is decreased to the low pressure level by the second expansion valve (6), such refrigerant is evaporated in the evaporator (3), and is sucked into the first compression mechanism (20).

Advantages of Sixth Embodiment

[0269] According to the sixth embodiment, the suction volume of intermediate-pressure refrigerant in the second operational state is larger than the suction volume of intermediate-pressure refrigerant in the first operational state. On the other hand, the suction volume of low-pressure refrigerant in the second operational state is smaller than the suction volume of low-pressure refrigerant in the first operational state.

[0270] In the first and second operational states, the suction volume of low-pressure refrigerant is smaller in the second operational state than in the first operational state, whereas the suction volume of intermediate-pressure refrigerant is the same between the first and second operational states.

[0271] As described above, in the present embodiment, refrigerant merely passes through one of the cylinder chambers (C1, C2) of the first compression mechanism (20) (inner cylinder chamber) in the second operational state. Thus, in the compressor (1) in which the two compression mechanisms (20, 30) are mechanically connected to a single shaft (53), the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Consequently, the suction volume ratio of the compressor (1) is adjusted depending on the operational conditions while performing an operation with high COP (coefficient of performance).

<<Seventh Embodiment of the Invention>>

[0272] A seventh embodiment of the present invention will be described with reference to FIGS. 30-34.

[0273] FIG. 30 is a longitudinal sectional view of a compressor (100) used for a refrigerating apparatus (air conditioning apparatus) of the seventh embodiment. FIG. 31 is a cross-sectional view of a compression mechanism (first compression mechanism (110)). FIGS. 32(A)-32(D) are views illustrating operational states in the compression mechanism (first compression mechanism (110)). FIG. 33 is a refrigerant circuit diagram illustrating a first operational state of the air conditioning apparatus, and FIG. 34 is a refrigerant circuit diagram illustrating a second operational state. The compressor (100) is used for compressing refrigerant sucked from an evaporator at two stages and discharging such refrigerant to a condenser in a refrigerant circuit of the air conditioning apparatus.

<Configuration of Compressor>

[0274] First, a configuration of the compressor (100) will be described. The compressor (100) is a rotary compressor, and includes the first compression mechanism (110), a second compression mechanism (120), a third compression mechanism (130), and a fourth compression mechanism (140) which are mechanically connected together through a single drive shaft (173). The compressor (100) is configured so that carbon dioxide which is refrigerant (working fluid) is compressed from a low pressure level to a high pressure level. Since the cross-sectional views and the operational state views of the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are the substantially same as those of the first compression mechanism (110), reference numerals of the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are shown in Fig 2 without details. The first compression mechanism (110) and the third compression mechanism (130) are of the same phase, and the second compression mechanism (120) and the fourth compression mechanism (140) are arranged so that their phases are shifted from the first compression mechanism (110) and the third compression mechanism (130) by 180°. However, for convenience of reference, such a phase difference is not shown in FIG. 2.

[0275] As illustrated in FIG. 30, the compressor (100) includes a casing (150) in which the first compression mechanism (110), the second compression mechanism (120), the third compression mechanism (130), the fourth compression mechanism (140), and an electrical motor (drive mechanism) (170) positioned above the compression mechanisms (110-140) are accommodated in this order from bottom to top; and is hermetic. In the present embodiment, later-described volume ratio changing units are provided, by which a combination of four cylinder chambers (C1, C2, C3, C4) of the compression mechanisms (110-140) is changed, and therefore a ratio of a suction volume of a low-pressure compression mechanism to a suction volume of a high-pressure compression mechanism is changed. A refrigerant flow in a refrigerant circuit (180) is switched, and therefore a combination of the compression mechanisms (110-140) to be used for the two-stage compression is switchable.

[0276] The casing (150) includes a cylindrical body section (151), an upper end plate (152) fixed to an upper end portion of the body section (151), and a lower end plate (153) fixed to a lower end portion of the body section (151). A suction port pipe (154) and a discharge port pipe (155) corresponding to each of the compression mechanisms (110-140) are provided in the casing (150). The suction port pipe (154) includes a first suction port pipe (154-1) corresponding to the first compression mechanism (110), a second suction port pipe (154-2) corresponding to the second compression mechanism (120), a third suction port pipe (154-3) corresponding to the third compression mechanism (130), and a fourth suction port pipe (154-4) corresponding to the fourth compression mechanism (140). The discharge port pipe includes a first discharge port pipe (155-1) corresponding to the first compression mechanism (110), a second discharge port pipe (155-2) corresponding to the second compression mechanism (120), a third discharge port pipe (155-3) corresponding to the third compression mechanism (130), and a fourth discharge port pipe (155-4) corresponding to the fourth compression mechanism (140). In addition, in the casing (150), a refrigerant injection port (156) is provided, through which refrigerant flowing through the refrigerant circuit (180) is injected into the casing (150).

[0277] The first compression mechanism (110), the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are stacked in four tiers, and are provided between a front head (157) fixed to the casing (150) and a rear head (158) below the first compression mechanism (110). Each of the compression mechanisms (110-140) is a rotary fluid machine which is one type of a positive-displacement fluid machine.

[0278] As described above, the first to fourth compression mechanisms (110-140) are arranged in this order from a bottom side of the casing (150) to top (the electrical motor (170) side). Middle plates (159) are provided, each of which is interposed between each pair of the compression mechanisms (110-140). The rear head (158) is fastened to the front head (157) with bolts (not shown in the figure) from bottom in a state in which each of the three middle plates (159) is sandwiched between each pair of the four compression mechanisms (110-140), thereby forming the compression mechanisms (110-140). The front head (157) is fixed to the casing (150), and therefore the compression mechanisms (110-140) are positioned within the casing (150).

[0279] Bearing sections (157a, 158a) are provided in the front head (157) and the rear head (158), respectively. A cover plate (160) is fixed to a lower surface of the rear head (158).

[0280] The electrical motor (170) includes a stator (171) and a rotor (172). The stator (171) is arranged above the fourth compression mechanism (140), and is fixed to the body section (151) of the casing (150). The rotor (172) is arranged inside the stator (171). A main shaft section of the drive shaft (crankshaft) (173) is connected to a center portion of the rotor (172), and the drive shaft (173) rotates together with the rotor (172). The center of the main shaft section is on the center of the casing (150).

[0281] As illustrated in FIG. 31, each of the compression mechanisms (110-140) includes a circular cylinder (111, 121, 131, 141) and a circular rotary piston (eccentric piston) (112, 122, 132, 142). As for the members with reference numerals in parentheses in FIG. 31, the reference numerals which are not in parentheses are reference numerals for the first compression mechanism (110), and the reference numerals in parentheses are reference numerals for the second to fourth compression mechanisms (120-140).

[0282] The cylinder (111, 121, 131, 141) and the rotary piston (112, 122, 132, 142) are sandwiched between the rear head (158) and the middle plate (159), between the middle plates (159), or between the middle plate (159) and the front head (157). An inner diameter of the cylinder (111, 121, 131, 141) is larger than an outer diameter of the rotary piston (112, 122, 132, 142). A cylinder chamber (C1, C2, C3, C4) is formed between an inner circumferential surface of the cylinder (111, 121, 131, 141) and an outer circumferential surface of the rotary piston (112, 122, 132, 142).

[0283] A flat plate-like blade (113, 123, 133, 143) is provided so as to protrude from the outer circumferential surface of the rotary piston (112, 122, 132, 142). The blade (113, 123, 133, 143) is slidably sandwiched between a pair of swing bushes (114, 124, 134, 144) which are provided so as to swing relative to the cylinder (111, 121, 131, 141). The rotary piston (112, 122, 132, 142) can swing relative to the cylinder (111, 121, 131, 141) together with the blade (113, 123, 133, 143). The blade (113, 123, 133, 143) divides the cylinder chamber (C1, C2, C3, C4) into two sections.

[0284] An eccentric section (173a, 173b, 173c, 173d) of the drive shaft (173) is rotatably fitted into an inside of the rotary piston (112, 122, 132, 142). The eccentric section (173a, 173b, 173c, 173d) has a diameter larger than that of the main shaft section, and is eccentric to the main shaft section. In the compressor (100), when rotating the drive shaft (173), an inner circumferential surface of the rotary piston (112, 122, 132, 142) slidably contacts an outer circumferential surface of the eccentric section (173a, 173b, 173c, 173d) through an oil film, and the outer circumferential surface of the rotary piston (112, 122, 132, 142) slidably contacts the inner circumferential surface of the cylinder (111, 121, 131, 141) through an oil film. Meanwhile, the rotary piston (112, 122, 132, 142) eccentrically rotates.

[0285] The suction port pipe (154-1, 154-2, 154-3, 154-4) is connected to the cylinder (111, 121, 131, 141) so as to be communicated with the cylinder chamber (C1, C2, C3, C4). The suction port pipe (154-1, 154-2, 154-3, 154-4) opens near one of the swing bushes (114, 124, 134, 144) (swing bush (114, 124, 134, 144) on the right side as viewed in FIG. 31). In the cylinder chamber (C1, C2, C3, C4), a side to which the suction port pipe (154-1, 154-2, 154-3, 154-4) opens is a low-pressure side. The "low-pressure side" includes a low-pressure side against an intermediate-pressure side, and an intermediate-pressure side against a high-pressure side.

[0286] For example, a discharge space (161, 162) is formed in each of the compression mechanisms (110-140), and the discharge port pipe (155-1, 155-2, 155-3, 155-4) is connected to the discharge space (161, 162). The discharge space (161, 162) is communicated with the cylinder chamber (C1, C2, C3, C4) through, e.g., an outlet (110a, 140a). In the discharge space (161, 162), e.g., a discharge valve (reed valve) (163, 164) configured to open/close the outlet (110a, 140a) (the discharge valves for the second and third compression mechanisms are not shown in the figure).

[0287] In the first to third compression mechanisms (110-130), the discharge port pipes (155-1, 155-2, 155-3) are communicated with, e.g., the discharge space (161). In the fourth compression mechanism (140), the discharge port pipe (155-4) is communicated with the discharge space (162) through a space inside the casing (150). The outlets (110a, 140a) of the first compression mechanism (110) and the fourth compression mechanism (140) open near the other swing bush (114, 124, 134, 144) (swing bush (114, 124, 134, 144) on the left side as viewed in FIG. 31). In the cylinder chamber (C1, C2, C3, C4), a side to which the outlet (110a, 140a) opens is a high-pressure side. The "high-pressure side" includes a high-pressure side against an intermediate-pressure side, and an intermediate-pressure side against a low-pressure side.

[0288] As described above, the compressor (100) includes the first compression mechanism (110), the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) each having the single cylinder chamber (C1, C2, C3, C4). Each of the compression mechanisms (110-140) includes the cylinder (111, 121, 131, 141) having a circular cylinder space, and the rotary piston (eccentric piston) (112, 122, 132, 142) eccentrically rotating in the cylinder space.

[0289] In the foregoing configuration, in the first to fourth compression mechanisms (110-140), suction volumes of the four cylinder chambers (C1, C2, C3, C4) are different. Specifically, in order to differentiate the suction volumes of the cylinder chambers (C1, C2, C3, C4), the length of the rotary piston (112, 122, 132, 142) in a shaft direction and the length of the corresponding cylinder (111, 121, 131, 141) in the shaft direction are different in each of the compression mechanisms (110-140). In the example illustrated in the figure, the lengths of the cylinder (111) and the rotary piston (112) of the first compression mechanism (110) in the shaft direction are longest, and the lengths of the cylinder (111, 121, 131, 141) and the rotary piston (112, 122, 132, 142) in the shaft direction are set so as to decrease in the order from the first compression mechanism (110) to the fourth compression mechanism (140).

[0290] An oil sump in which lubricant oil is stored is formed in a bottom portion of the casing (150). A centrifugal oil pump (174) soaked in the lubricant oil of the oil sump is provided in a lower end portion of the drive shaft (173). The oil pump is connected to an oil supply path (not shown in the figure) vertically extending inside the drive shaft (173). The oil pump (174) is configured to supply the lubricant oil to sliding sections of the first compression mechanism (110) and the second compression mechanism (120), and the bearing sections of the drive shaft (173) through the oil supply path.

<Configuration of Refrigerant Circuit>

[0291] In the refrigerant circuit (180) of the air conditioning apparatus, carbon dioxide which is refrigerant is compressed to a supercritical pressure level by the compressor (100), thereby performing a refrigeration cycle. As illustrated in FIGS. 33 and 34, the refrigerant circuit (180) includes the compressor (100), a gas cooler (102), an evaporator (103), a gas-liquid separator (104), a first expansion valve (105), and a second expansion valve (106). The refrigerant circuit (180) further includes a first three-way valve (switching mechanism) (107a) on an inlet side of the compressor (100), and a second three-way valve (switching mechanism) (107b) on an outlet side of the compressor (100).

[0292] A low-pressure refrigerant pipe (181) connected to a gas-side end of the evaporator (103) branches into a first suction pipe (182a) and a second section pipe (182b). The first suction pipe (182a) is connected to the first suction port pipe (154-1) of the compressor (100), and the second section pipe (182b) is connected to the second suction port pipe (154-2).

[0293] A first discharge pipe (183a) is connected to the first discharge port pipe (155-1) of the compressor (100), and a second discharge pipe (183b) is connected to the second discharge port pipe (155-2). The first discharge pipe (183a) and the second discharge pipe (183b) join together, and then branch into an intermediate-pressure refrigerant pipe (184) and a first connecting pipe (189a). The intermediate-pressure refrigerant pipe (184) is connected to a refrigerant gas outlet (104a) of the gas-liquid separator (104). The first connecting pipe (189a) is connected to a third port (P3) of the second three-way valve (107b).

[0294] The intermediate-pressure refrigerant pipe (184) branches into a branched pipe (185) downstream the refrigerant gas outlet (104a) of the gas-liquid separator (104). The branched pipe (185) is connected to a second port (P2) of the first three-way valve (107a). One end of a third suction pipe (182c) is connected to a first port (P1) of the first three-way valve (107a), and the other end of the third suction pipe (182c) is connected to the third suction port pipe (154-3) of the compressor (100). The branched pipe (185) branches into a fourth suction pipe (182d) between a point at which the branched pipe (185) is connected to the intermediate-pressure refrigerant pipe (184) and a point at which the branched pipe (185) is connected to the first three-way valve (107a). The fourth suction pipe (182d) is connected to the fourth suction port pipe (154-4) of the compressor (100). The second section pipe (182b) branches into a second connecting pipe (189b) between the second suction port pipe (154-2) and the low-pressure refrigerant pipe (181), and the second connecting pipe (189b) is connected to a third port (P3) of the first three-way valve (107a).

[0295] The third discharge port pipe (155-3) is connected to a first port (P1) of the second three-way valve (107b) through a third discharge pipe (183c). A second port (P2) of the second three-way valve (107b) is connected to the refrigerant injection port (156) through a high-pressure refrigerant injection pipe (186).

[0296] The fourth discharge port pipe (155-4) of the compressor (100) is connected to one end of a high-pressure refrigerant pipe (fourth discharge pipe) (187). The other end of the high-pressure refrigerant pipe (187) is connected to an inlet (104b) of the gas-liquid separator (104) through the gas cooler (102) and the first expansion valve (105). An outlet (104c) of the gas-liquid separator (104) is connected to a liquid-side end of the evaporator (103) through a liquid pipe (188) including the second expansion valve (106) in the middle thereof.

[0297] In the foregoing configuration, the branched pipe (185) serves as an injection mechanism (injection pipe) through which intermediate-pressure refrigerant is injected to the compression mechanisms (110-140).

[0298] Each of the three-way valves (107a, 107b) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other (see FIG. 33), and a second position in which the first port (P1) and the third port (P3) are communicated with each other (see FIG. 34).

[0299] The three-way valve (107a, 107b) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110-140). The three-way valve (107a, 107b) is configured so that, by changing a combination of the four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (180), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed. That is, the switching mechanism (107a, 107b) can change the four cylinder chambers (C1, C2, C3, C4), i.e., the cylinder chambers used as the low-pressure compression mechanism and the cylinder chambers used as the high-pressure compression mechanism.

[0300] The switching mechanism (107a, 107b) is switchable between a state illustrated in FIG. 33, in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism; and a state illustrated in FIG. 34, in which the first compression mechanism (110), the second compression mechanism (120), and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the fourth compression mechanism (140) is used as the high-pressure compression mechanism.

[0301] The switching mechanism (volume ratio changing unit) (107a, 107b) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

<Operation of Compressor (100)>

[0302] An operation of the compressor (100) will be described. In the compressor (100), when starting the electrical motor (170), rotation of the drive shaft (173) drives each of the compression mechanisms (110-140), and therefore refrigerant is compressed in each of the compression mechanisms (110-140). The operation itself is the substantially same in the compression mechanisms (110-140). Thus, only the operation of the first compression mechanism (110) will be described below, and the description of the operations of the other compression mechanisms (120-140) will not be repeated.

[0303] A process in which refrigerant flows into the compressor (100) will be described with reference to FIGS. 32(A)-32(D). When the drive shaft (173) slightly rotates from a state in which an angle of rotation is 0° as illustrated in FIG. 32(A), and a point where the first rotary piston (112) and the first cylinder (111) contact each other passes through an opening of the first suction port pipe (154-1), refrigerant begins to flow into the first outer cylinder chamber (C1) through the first suction port pipe (154-1). Then, refrigerant flows into the first outer cylinder chamber (C1) as the angle of rotation of the drive shaft (173) is increased to 90° as illustrated in FIG. 32(B), 180° as illustrated in FIG. 32(C), and 270° as illustrated in FIG. 32(D), and refrigerant continuously flows into the first outer cylinder chamber (C1) until the angle of rotation reaches 360° as illustrated in FIG. 32(A).

[0304] Subsequently, a process in which refrigerant is compressed in the first compression mechanism (110) will be described. In the state in which the flowing of refrigerant into the first outer cylinder chamber (C1) is completed (the angle of rotation of the drive shaft (173) is 360° (0°)), when the drive shaft (173) further slightly rotates from the state in which the angle of rotation is 0°, the point where the first rotary piston (112) and the first cylinder (111) contact each other passes through the opening of the first suction port pipe (154-1). As soon as such a contact point passes through the opening of the first suction port pipe (154-1), trapping of refrigerant in the first compression mechanism (110) is completed. When further rotating the drive shaft (173) from such a state, compression of refrigerant is started. When the pressure of refrigerant in the first outer cylinder chamber (C1) exceeds the pressure of refrigerant outside the outlet (110a), the discharge valve (163) is opened, and refrigerant is discharged to outside the first outer cylinder chamber (C1) through the outlet (110a). The discharge of refrigerant is continued until the angle of rotation of the drive shaft (173) reaches 360°.

<Operation of Air Conditioning Apparatus>

[0305] In the air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 33 and a second operational state illustrated in FIG. 34 depending on the change in operational conditions. Note that the operation which will be described below is assumed as a cooling operation.

[0306] In the first operational state illustrated in FIG. 34, the first three-way valve (107a) and the second three-way valve (107b) are set to the first position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into intermediate-pressure refrigerant in the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2).

[0307] The intermediate-pressure refrigerant discharged from the cylinder chambers (C1, C2) passes through the first discharge pipe (183a) and the second discharge pipe (183b), respectively, and joins together in the intermediate-pressure refrigerant pipe (184). Then, such refrigerant joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, such refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0308] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into the casing (150) of the compressor (100) through the second three-way valve (107b), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). Meanwhile, the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0309] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

[0310] In the second operational state illustrated in FIG. 34, the first three-way valve (107a) and the second three-way valve (107b) are set to the second position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a), the second section pipe (182b), and the third suction pipe (182c) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2), and the refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1), the second cylinder chamber (C2), and the third cylinder chamber (C3).

[0311] The intermediate-pressure refrigerant discharged from the cylinder chambers (C1, C2, C3) passes through the first discharge pipe (183a), the second discharge pipe (183b), and the third discharge pipe (183c), respectively, and joins together in the intermediate-pressure refrigerant pipe (184). Such refrigerant further joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) flows into the fourth suction pipe (182d). The intermediate-pressure refrigerant is sucked into the fourth compression mechanism (140) through the fourth suction pipe (182d) and the fourth discharge port pipe (155-4). Then, the refrigerant is compressed into high-pressure refrigerant in the fourth cylinder chamber (C4).

[0312] The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150). The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the fourth compression mechanism (140).

Advantages of Seventh Embodiment

[0313] According to the present embodiment, the suction volume of low-pressure refrigerant in the second operational state is larger than the suction volume of low-pressure refrigerant in the first operational state. In addition, the suction volume of intermediate-pressure refrigerant in the second operational state is smaller than the suction volume of intermediate-pressure refrigerant in the first operational state.

[0314] That is, in the first and second operational states, a suction amount at the low-pressure stage is larger in the second operational state than in the first operational state, whereas a suction amount at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0315] As described above, in the present embodiment, the cylinder chambers (C1, C2, C3, C4) of the compression mechanisms (110-140) are used while changing their combination between the first and second operational states. Thus, in the compressor (100) in which the four compression mechanisms (110-140) are mechanically connected to the single shaft, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. In such a manner, the suction volume ratio of the compressor (100) is adjusted depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

[0316] For example, a case is considered, where the suction volume ratio is adjusted by unloading the low-pressure or high-pressure compression mechanism in the two-stage compression mechanism. However, unlike such an example, refrigerant is not compressed in the middle of a compression stroke in the present embodiment, thereby realizing a smooth operation.

<<Eighth Embodiment of the Invention>>

[0317] An eighth embodiment will be described with reference to FIGS. 35 and 36.

[0318] The present embodiment has a structure of a compressor (100) same as that of the seventh embodiment, and has a configuration of a refrigerant circuit (180) different from that of the seventh embodiment. Thus, only the refrigerant circuit (180) will be described below. Note that components of the refrigerant circuit (180) are the same as those of the seventh embodiment.

[0319] As illustrated in FIGS. 35 and 36, a low-pressure refrigerant pipe (181) connected to a gas-side end of an evaporator (103) is connected to a first suction port pipe (154-1) through a first suction pipe (182a). The low-pressure refrigerant pipe (181) branches into a connecting pipe (189c) on an outlet side of the evaporator (103), and the connecting pipe (189c) is connected to a second port (P2) of a first three-way valve (107a). One end of a third suction pipe (182c) is connected to a first port (P1) of the first three-way valve (107a), and the other end of the third suction pipe (182c) is connected to a third suction port pipe (154-3).

[0320] A first discharge pipe (183a) is connected to a first discharge port pipe (155-1) of the compressor (100). The first discharge pipe (183a) is connected to one end of an intermediate-pressure refrigerant pipe (184), and the other end of the intermediate-pressure refrigerant pipe (184) is connected to a refrigerant gas outlet (104a) of a gas-liquid separator (104). One end of a third discharge pipe (183c) is connected to a third discharge port pipe (155-3), and the other end of the third discharge pipe (183c) is connected to a first port (P1) of a second three-way valve (107b). One end of a connecting pipe (189d) is connected to a second port (P2) of the second three-way valve (107b), and the other end of the connecting pipe (189d) joins the first discharge pipe (183a) and is connected to the intermediate-pressure refrigerant pipe (184).

[0321] The intermediate-pressure refrigerant pipe (184) branches into a first branched pipe (185) downstream the refrigerant gas outlet (104a) of the gas-liquid separator (104). The branched pipe (185) is connected to a third port (P3) of the first three-way valve (107a). The branched pipe (185) branches into a second branched pipe (185b) between a point where the branched pipe (185) and the intermediate-pressure refrigerant pipe (184) are connected together, and a point where the branched pipe (185) and the first three-way valve (107a) are connected together. The second branched pipe (185b) further branches into a second section pipe (182b) and a fourth suction pipe (182d). The second section pipe (182b) is connected to a second suction port pipe (154-2) of the compressor (100), and the fourth suction pipe (182d) is connected to a fourth suction port pipe (154-4).

[0322] A third port (P3) of the second three-way valve (107b) is connected to a refrigerant injection port (156) through a high-pressure refrigerant injection pipe (186). One end of a second discharge pipe (183b) is connected to a second discharge port pipe (155-2), and the other end of the second discharge pipe (183b) is connected to the high-pressure refrigerant injection pipe (186).

[0323] A fourth discharge port pipe (155-4) of the compressor (100) is connected to one end of a high-pressure refrigerant pipe (187). The other end of the high-pressure refrigerant pipe (187) is connected to an inlet (104b) of the gas-liquid separator (104) through a gas cooler (102) and a first expansion valve (105). An outlet (104c) of the gas-liquid separator (104) is connected to a liquid-side end of the evaporator (103) through a liquid pipe (188) including a second expansion valve (106) in the middle thereof.

[0324] In the foregoing configuration, the branched pipe (185) serves as an injection mechanism through which intermediate-pressure refrigerant is injected to compression mechanisms (110-140).

[0325] Each of the three-way valves (107a, 107b) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other (see FIG. 35), and a second position in which the first port (P1) and the third port (P3) are communicated with each other (see FIG. 36).

[0326] The three-way valve (107a, 107b) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110-140). The three-way valve (107a, 107b) is configured so that, by changing a combination of four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (180), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0327] The switching mechanism (107a, 107b) is switchable between a state illustrated in FIG. 35, in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism; and a state illustrated in FIG. 36, in which the first compression mechanism (110) is used as the low-pressure compression mechanism, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are used as the high-pressure compression mechanism.

[0328] The switching mechanism (volume ratio changing unit) (107a, 107b) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0329] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 35 and a second operational state illustrated in FIG. 36 depending on the change in operational conditions.

[0330] In the first operational state illustrated in FIG. 35, the first three-way valve (107a) and the second three-way valve (107b) are set to the first position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the third suction pipe (182c) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the third cylinder chamber (C3).

[0331] The intermediate-pressure refrigerant discharged from the first cylinder chamber (C1) flows through the first discharge pipe (183a), and the intermediate-pressure refrigerant discharged from the third cylinder chamber (C3) flows through the third discharge pipe (183c), the second three-way valve (107b), and the connecting pipe (189d). Such refrigerant joins together in the intermediate-pressure refrigerant pipe (184). The intermediate-pressure refrigerant joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the first branched pipe (185). The intermediate-pressure refrigerant further branches into the second branched pipe (185b) from the first branched pipe (185). Then, the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2), and the refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). The refrigerant is compressed into high-pressure refrigerant in the second cylinder chamber (C2) and the fourth cylinder chamber (C4).

[0332] After passing through the second discharge pipe (183b) and the high-pressure, refrigerant injection pipe (186), the high-pressure refrigerant discharged through the second discharge port pipe (155-2) is injected into the casing (150) of the compressor (100) through the refrigerant injection port (156). Meanwhile, the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from a discharge space (162) of a front head (157) to a space inside the casing (150). Thus, the high-pressure refrigerant compressed in the second cylinder chamber (C2) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0333] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to a low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the third compression mechanism (130). The gas refrigerant in the gas-liquid separator (104) is injected to the second compression mechanism (120) and the fourth compression mechanism (140).

[0334] In the second operational state illustrated in FIG. 36, the first three-way valve (107a) and the second three-way valve (107b) are set to the second position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) flows into the first suction pipe (182a) through the low-pressure refrigerant pipe (181), and is sucked into the first compression mechanism (110) through the first suction pipe (182a) and the first suction port pipe (154-1). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1).

[0335] The intermediate-pressure refrigerant discharged from the first cylinder chamber (C1) is discharged from the first discharge pipe (183a), and flows into the intermediate-pressure refrigerant pipe (184). Such refrigerant joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the first branched pipe (185). The intermediate-pressure refrigerant flowing through the first branched pipe (185) branches into the second section pipe (182b), the third suction pipe (182c), and the fourth suction pipe (182d). The refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2), the refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the second cylinder chamber (C2), the third cylinder chamber (C3), and the fourth cylinder chamber (C4).

[0336] The high-pressure refrigerant compressed in the second cylinder chamber (C2) is discharged through the second discharge port pipe (155-2), and flows through the second discharge pipe (183b) toward the refrigerant injection port (156). Meanwhile, the high-pressure refrigerant compressed in the third cylinder chamber (C3) is discharged through the third discharge port pipe (155-3), and flows through the third discharge pipe (183c) and the high-pressure refrigerant injection pipe (186) toward the refrigerant injection port (156). The high-pressure refrigerant discharged from the second cylinder chamber (C2) and the high-pressure refrigerant discharged from the third cylinder chamber (C3) join together in the high-pressure refrigerant injection pipe (186), and flows into the casing (150) through the refrigerant injection port (156).

[0337] The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150). In the casing (150), the high-pressure refrigerant discharged from the second cylinder chamber (C2) and the third cylinder chamber (C3) and the high-pressure refrigerant discharged from the fourth cylinder chamber (C4) are mixed together. Then, the high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110). The gas refrigerant in the gas-liquid separator (104) is injected to the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140).

Advantages of Eighth Embodiment

[0338] According to the present embodiment, the suction volume of low-pressure refrigerant in the second operational state is smaller than the suction volume of low-pressure refrigerant in the first operational state. In addition, the suction volume of intermediate-pressure refrigerant in the second operational state is larger than the suction volume of intermediate-pressure refrigerant in the first operational state.

[0339] That is, in the first and second operational states, a suction amount at the low-pressure stage is smaller in the second operational state than in the first operational state, whereas a suction amount at the high-pressure stage is larger in the second operational state than in the first operational state.

[0340] As described above, in the present embodiment, the cylinder chambers (C1, C2, C3, C4) of the compression mechanisms (110-140) are used while changing their combination between the first and second operational states. Thus, in the compressor (100) in which the four compression mechanisms (110-140) are mechanically connected to a single shaft, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. In such a manner, the suction volume ratio of the compressor (100) is switched depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

<<Ninth Embodiment of the Invention>>

[0341] A ninth embodiment will be described with reference to FIGS. 37 and 38.

[0342] The ninth embodiment has a structure of a compressor (100) same as that of the seventh embodiment, and has a configuration of a refrigerant circuit (180) different from that of the seventh embodiment. Thus, only the refrigerant circuit (180) will be described below. Note that, in the present embodiment, four-way switching valves (108a, 108b) are used as components of the refrigerant circuit (180) instead of the three-way valves (107a, 107b).

[0343] As illustrated in FIGS. 37 and 38, a low-pressure refrigerant pipe (181) connected to a gas-side end of an evaporator (103) is connected to a first suction port pipe (154-1) through a first suction pipe (182a). The low-pressure refrigerant pipe (181) branches into a connecting pipe (189e) on an outlet side of the evaporator (103), and the connecting pipe (189e) is connected to a second port (P2) of the first four-way switching valve (108a). One end of a second section pipe (182b) is connected to a first port (P1) of the first four-way switching valve (108a), and the other end of the second section pipe (182b) is connected to a second suction port pipe (154-2).

[0344] A first discharge pipe (183a) is connected to a first discharge port pipe (155-1) of the compressor (100), and a second discharge pipe (183b) is connected to a second discharge port pipe (155-2). The first discharge pipe (183a) is connected to one end of an intermediate-pressure refrigerant pipe (184), and the other end of the intermediate-pressure refrigerant pipe (184) is connected to a refrigerant gas outlet (104a) of a gas-liquid separator (104). The second discharge pipe (183b) is connected to a first port (P1) of the second four-way switching valve (108b). The first discharge pipe (183a) branches into a connecting pipe (189f), and the connecting pipe (189f) is connected to a second port (P2) of the second four-way switching valve (108b).

[0345] The intermediate-pressure refrigerant pipe (184) branches into a branched pipe (185) downstream the refrigerant gas outlet (104a) of the gas-liquid separator (104). The branched pipe (185) is connected to a fourth port (P4) of the first four-way switching valve (108a). One end of a third suction pipe (182c) is connected to a third port (P3) of the first four-way switching valve (108a), and the other end of the third suction pipe (182c) is connected to a third suction port pipe (154-3) of the compression mechanism. The branched pipe (185) branches into a fourth suction pipe (182d) between a point where the branched pipe (185) and the intermediate-pressure refrigerant pipe (184) are connected together, and a point where the branched pipe (185) and the first four-way switching valve (108a) are connected together, and the fourth suction pipe (182d) is connected to a fourth suction port pipe (154-4) of the compressor (100).

[0346] The third discharge port pipe (155-3) is connected to a third port (P3) of the second four-way switching valve (108b) through a third discharge pipe (183c). A fourth port (P4) of the second four-way switching valve (108b) is connected to a refrigerant injection port (156) through a high-pressure refrigerant injection pipe (186).

[0347] A fourth discharge port pipe (155-4) of the compressor (100) is connected to one end of a high-pressure refrigerant pipe (187). The other end of the high-pressure refrigerant pipe (187) is connected to an inlet (104b) of the gas-liquid separator (104) through a gas cooler (102) and a first expansion valve (105). An outlet (104c) of the gas-liquid separator (104) is connected to a liquid-side end of the evaporator (103) through a liquid pipe (188) including a second expansion valve (106) in the middle thereof.

[0348] In the foregoing configuration, the branched pipe (185) serves as an injection mechanism through which intermediate-pressure refrigerant is injected to the compression mechanisms (110-140).

[0349] Each of the four-way valves (108a, 108b) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other, and the third port (P3) and the fourth port (P4) are communicated with each other (see FIG. 37); and a second position in which the first port (P1) and the fourth port (P4) are communicated with each other, and the second port (P2) and the third port (P3) are communicated with each other (see FIG. 38).

[0350] The four-way valve (108a, 108b) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110-140). The four-way valve (108a, 108b) is configured so that, by changing a combination of four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (180), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0351] The switching mechanism (108a, 108b) is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism; and a state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism.

[0352] The switching mechanism (volume ratio changing unit) (108a, 108b) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0353] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 37 and a second operational state illustrated in FIG. 38 depending on the change in operational conditions.

[0354] In the first operational state illustrated in FIG. 37, the first four-way switching valve (108a) and the second four-way switching valve (108b) are set to the first position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the second cylinder chamber (C2).

[0355] The intermediate-pressure refrigerant discharged from the cylinder chambers (C1, C2) passes through the first discharge pipe (183a) and the second discharge pipe (183b), respectively, and joins together in the intermediate-pressure refrigerant pipe (184). Such refrigerant further joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0356] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into the casing (150) of the compressor (100) through the second four-way switching valve (108b), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). Meanwhile, the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from a discharge space (162) of a front head (157) to a space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0357] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to a low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

[0358] In the second operational state illustrated in FIG. 38, the first four-way switching valve (108a) and the second four-way switching valve (108b) are set to the second position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the third suction pipe (182c) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the third cylinder chamber (C3).

[0359] The intermediate-pressure refrigerant discharged from the cylinder chambers (C1, C3) passes through the first discharge pipe (183a) and the third discharge pipe (183c), respectively, and joins together in the intermediate-pressure refrigerant pipe (184). Such refrigerant further joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the second section pipe (182b) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the second cylinder chamber (C2) and the fourth cylinder chamber (C4).

[0360] The high-pressure refrigerant discharged through the second discharge port pipe (155-2) is injected into the casing (150) of the compressor (100) through the second four-way switching valve (108b), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). Meanwhile, the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150). Thus, the high-pressure refrigerant compressed in the second cylinder chamber (C2) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0361] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the third compression mechanism (130). The gas refrigerant in the gas-liquid separator (104) is injected to the second compression mechanism (120) and the fourth compression mechanism (140).

Advantages of Ninth Embodiment

[0362] According to the ninth embodiment, the suction volume of low-pressure refrigerant in the second operational state is smaller than the suction volume of low-pressure refrigerant in the first operational state. In addition, the suction volume of intermediate-pressure refrigerant in the second operational state is larger than the suction volume of intermediate-pressure refrigerant in the first operational state.

[0363] That is, in the first and second operational states, a suction amount at the low-pressure stage is smaller in the second operational state than in the first operational state, whereas a suction amount at the high-pressure stage is larger in the second operational state than in the first operational state.

[0364] As described above, in the present embodiment, the cylinder chambers (C1, C2, C3, C4) of the compression mechanisms (110-140) are used while changing their combination between the first and second operational states. Thus, in the compressor (100) in which the four compression mechanisms (110-140) are mechanically connected to a single shaft, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. In such a manner, the volume ratio of the compressor (100) is switched depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

<<Tenth Embodiment of the Invention>>

[0365] A tenth embodiment will be described with reference to FIGS. 39 and 40.

[0366] The tenth embodiment has a structure of a compressor (100) same as that of the seventh embodiment, and has a configuration of a refrigerant circuit (180) different from that of the seventh embodiment. Thus, only the refrigerant circuit (180) will be described below. Note that the present embodiment is different from the first embodiment in that a three-way valve or a four-way valve is not used on an inlet side of the compressor (100) as components of the refrigerant circuit (180).

[0367] As illustrated in FIGS. 39 and 40, a low-pressure refrigerant pipe (181) connected to a gas-side end of an evaporator (103) branches into a first suction pipe (182a) and the second section pipe (182b). The first suction pipe (182a) is connected to a first suction port pipe (154-1) of the compressor (100), and the second section pipe (182b) is connected to a second suction port pipe (154-2).

[0368] A first discharge pipe (183a) is connected to a first discharge port pipe (155-1) of the compressor (100), and a second discharge pipe (183b) is connected to a second discharge port pipe (155-2). The first discharge pipe (183a) and the second discharge pipe (183b) join together, and are connected to an intermediate-pressure refrigerant pipe (184). The intermediate-pressure refrigerant pipe (184) is connected to a refrigerant gas outlet (104a) of a gas-liquid separator (104). The second discharge pipe (183b) branches into a connecting pipe (189g). The connecting pipe (189g) is connected to a third port (P3) of a three-way valve (107).

[0369] The intermediate-pressure refrigerant pipe (184) branches into a branched pipe (185) downstream the refrigerant gas outlet (104a) of the gas-liquid separator (104). The branched pipe (185) branches into a third suction pipe (182c) and a fourth suction pipe (182d). The third suction pipe (182c) is connected to a third suction port pipe (154-3) of a third compression mechanism (130). In addition, the fourth suction pipe (182d) is connected to a fourth suction port pipe (154-4) of the compressor (100).

[0370] The third discharge port pipe (155-3) is connected to a first port (P1) of the three-way valve (107) through a third discharge pipe (183c). A second port (P2) of the three-way valve (107) is connected to a refrigerant injection port (156) through a high-pressure refrigerant injection pipe (186).

[0371] A fourth discharge port pipe (155-4) of the compressor (100) is connected to one end of a high-pressure refrigerant pipe (187). The other end of the high-pressure refrigerant pipe (187) is connected to an inlet (104b) of the gas-liquid separator (104) through a gas cooler (102) and a first expansion valve (105). An outlet (104c) of the gas-liquid separator (104) is connected to a liquid-side end of the evaporator (103) through a liquid pipe (188) including a second expansion valve (106) in the middle thereof.

[0372] In the foregoing configuration, the branched pipe (185) serves as an injection mechanism through which intermediate-pressure refrigerant is injected to the compression mechanisms (110-140).

[0373] The three-way valve (107) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other (see FIG. 39), and a second position in which the first port (P1) and the third port (P3) are communicated with each other (see FIG. 40).

[0374] The three-way valve (107) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110-140). The three-way valve (107) is configured so that, by changing a combination of four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (180), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0375] When the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the switching mechanism (107) is switchable between a state in which refrigerant is compressed in both of the third compression mechanism (130) and the fourth compression mechanism (140) to provide a difference between a suction pressure and a discharge pressure; and a state in which refrigerant is compressed in one of the third compression mechanism (130) and the fourth compression mechanism (140) (in the fourth compression mechanism (140)) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other compression mechanism (third compression mechanism (130)) allow uncompressed refrigerant to pass through such a compression mechanism.

[0376] The switching mechanism (volume ratio changing unit) (107) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0377] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 39 and a second operational state illustrated in FIG. 40 depending on the change in operational conditions.

[0378] In the first operational state illustrated in FIG. 39, the three-way valve (107) is set to the first position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the second cylinder chamber (C2).

[0379] The intermediate-pressure refrigerant discharged from the cylinder chambers (C1, C2) passes through the first discharge pipe (183a) and the second discharge pipe (183b), respectively, and joins together in the intermediate-pressure refrigerant pipe (184). Such refrigerant further joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0380] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into a casing (150) of the compressor (100) through the three-way valve (107), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). Meanwhile, the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from a discharge space (162) of a front head (157) to a space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0381] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to a low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

[0382] In the second operational state illustrated in FIG. 40, the three-way valve (107) is set to the second position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the second cylinder chamber (C2).

[0383] The intermediate-pressure refrigerant discharged from the cylinder chambers (C1, C2) passes through the first discharge pipe (183a) and the second discharge pipe (183b), respectively, and joins together in the intermediate-pressure refrigerant pipe (184). Such refrigerant joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4).

[0384] In such a state, the three-way valve (107) is switched to the second position, and therefore the third discharge pipe (183c) and the second discharge pipe (183b) are communicated with each other under an intermediate pressure. Thus, refrigerant is not substantially compressed in the third compression mechanism (130), and the intermediate-pressure refrigerant is discharged as it is.

[0385] Meanwhile, the refrigerant is compressed into high-pressure refrigerant in the fourth cylinder chamber (C4) of the fourth compression mechanism (140).

[0386] The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150). The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

Advantages of Tenth Embodiment

[0387] According to the present embodiment, in the first operational state, the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism. On the other hand, in the second operational state, intermediate-pressure refrigerant merely passes through the third compression mechanism (130) as it is. Thus, the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and only the fourth compression mechanism (140) is used as the high-pressure compression mechanism.

[0388] Consequently, the suction volume at the low-pressure stage is the same between the first and second operational states, whereas the suction volume at the high-pressure stage is smaller in the second operational state than in the first operational state. That is, a suction amount at the low-pressure stage is the same in the first and second operational states, but a substantive suction amount at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0389] As described above, in the present embodiment, refrigerant is not compressed in the third compression mechanism (130) in the second operational state. Thus, in the compressor (100) in which the four compression mechanisms (110-140) are mechanically connected to a single shaft, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Thus, the volume ratio of the compressor (100) is switched depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

<<Eleventh Embodiment of the Invention>>

[0390] An eleventh embodiment will be described with reference to FIGS. 41 and 42.

[0391] The present embodiment has a structure of a compressor (100) same as that of the seventh embodiment, and has a configuration of a refrigerant circuit (180) different from that of the seventh embodiment. Thus, only the refrigerant circuit (180) will be described below. Note that the present embodiment is different from the seventh embodiment in that a three-way valve or a four-way valve is not used on an outlet side of the compressor (100) as components of the refrigerant circuit (180).

[0392] As illustrated in FIGS. 41 and 42, a low-pressure refrigerant pipe (181) connected to a gas-side end of an evaporator (103) is connected to a first suction port pipe (154-1) of a first compression mechanism (110) through a first suction pipe (182a). The first suction pipe (182a) branches into a connecting pipe (189h), and the connecting pipe (189h) is connected to a second port (P2) of a three-way valve (107).

[0393] A first discharge pipe (183a) is connected to a first discharge port pipe (155-1) of the compressor (100), and a second discharge pipe (183b) is connected to a second discharge port pipe (155-2). The first discharge pipe (183a) and the second discharge pipe (183b) join together, and are connected to an intermediate-pressure refrigerant pipe (184). The intermediate-pressure refrigerant pipe (184) is connected to a refrigerant gas outlet (104a) of a gas-liquid separator (104).

[0394] The intermediate-pressure refrigerant pipe (184) branches into a branched pipe (185) downstream the refrigerant gas outlet (104a) of the gas-liquid separator (104). The branched pipe (185) is connected to a third port (P3) of the three-way valve (107). One end of a second section pipe (182b) is connected to a first port (P1) of the three-way valve (107), and the other end of the second section pipe (182b) is connected to a second suction port pipe (154-2) of a second compression mechanism (120). The branched pipe (185) branches into a third suction pipe (182c) and a fourth suction pipe (182d) between a point where the branched pipe (185) and the intermediate-pressure refrigerant pipe (184) are connected together, and a point where the branched pipe (185) and the three-way valve (107) are connected together. The third suction pipe (182c) is connected to a third suction port pipe (154-3) of a third compression mechanism (130), and the fourth suction pipe (182d) is connected to a fourth suction port pipe (154-4) of a fourth compression mechanism (140).

[0395] A third discharge port pipe (155-3) is connected to a refrigerant injection port (156) through a third discharge pipe (183c) and a high-pressure refrigerant injection pipe (186). The third discharge pipe (183c) and the high-pressure refrigerant injection pipe (186) form a single pipe.

[0396] A fourth discharge port pipe (155-4) of the compressor (100) is connected to one end of a high-pressure refrigerant pipe (187). The other end of the high-pressure refrigerant pipe (187) is connected to an inlet (104b) of the gas-liquid separator (104) through a gas cooler (102) and a first expansion valve (105). An outlet (104c) of the gas-liquid separator (104) is connected to a liquid-side end of the evaporator (103) through a liquid pipe (188) including a second expansion valve (106) in the middle thereof.

[0397] In the foregoing configuration, the branched pipe (185) serves as an injection mechanism through which intermediate-pressure refrigerant is injected to the compression mechanisms (110-140).

[0398] The three-way valve (107) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other (see FIG. 41), and a second position in which the first port (P1) and the third port (P3) are communicated with each other (see FIG. 42).

[0399] The three-way valve (107) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110-140). The three-way valve (107) is configured so that, by changing a combination of four cylinder chambers (C1, C2, C3, C4) in the refrigerant circuit (180), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0400] The switching mechanism (107) is switchable between a state in which, when the first compression mechanism (110) and the second compression mechanism (120) serve as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) serve as the high-pressure compression mechanism, refrigerant is compressed in both of the low-pressure and high-pressure compression mechanisms to provide a difference between a suction pressure and a discharge pressure; and a state in which, when the first compression mechanism (110) serves as the low-pressure compression mechanism, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) serve as the high-pressure compression mechanism, refrigerant is compressed in the low-pressure compression mechanism to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140) at the high-pressure stage allow uncompressed refrigerant to pass through such a compression mechanism.

[0401] The switching mechanism (volume ratio changing unit) (107) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0402] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 41 and a second operational state illustrated in FIG. 42 depending on the change in operational conditions.

[0403] In the first operational state illustrated in FIG. 41, the three-way valve (107) is set to the first position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the second cylinder chamber (C2).

[0404] The intermediate-pressure refrigerant discharged from the cylinder chambers (C1, C2) passes through the first discharge pipe (183a) and the second discharge pipe (183b), respectively, and joins together in the intermediate-pressure refrigerant pipe (184). Such refrigerant further joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0405] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into a casing (150) of the compressor (100) through the third discharge pipe (183c), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from a discharge space (162) of a front head (157) to a space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0406] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to a low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

[0407] In the second operational state illustrated in FIG. 42, the three-way valve (107) is set to the second position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) is sucked into the first compression mechanism (110) through the low-pressure refrigerant pipe (181), the first suction pipe (182a), and the first suction port pipe (154-1). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1).

[0408] The intermediate-pressure refrigerant discharged from the first cylinder chamber (C1) passes through the first discharge pipe (183a), and flows into the intermediate-pressure refrigerant pipe (184). Then, the intermediate-pressure refrigerant joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the second section pipe (182b), the third suction pipe (182c), and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2), the refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4).

[0409] The second discharge pipe (183b) joins the first discharge pipe (183a), and is connected to the intermediate-pressure refrigerant pipe (184). Thus, an outlet side of the second compression mechanism (120) is constantly under an intermediate pressure. Consequently, the intermediate-pressure refrigerant sucked into the second compression mechanism (120) is not substantially compressed, and flows out from the second compression mechanism (120) as it is.

[0410] Meanwhile, in the third compression mechanism (130) and the fourth compression mechanism (140), the refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0411] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into the casing (150) of the compressor (100) through the third discharge pipe (183c), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0412] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110). The gas refrigerant in the gas-liquid separator (104) is injected to the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140).

Advantages of Eleventh Embodiment

[0413] According to the present embodiment, in the first operational state, the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism. On the other hand, in the second operational state, intermediate-pressure refrigerant passes through the second compression mechanism (120) as it is. Thus, only the first compression mechanism (110) is used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism.

[0414] Consequently, the suction volume at the high-pressure stage is the same between the first and second operational states, whereas the suction volume at the low-pressure stage is smaller in the second operational state than in the first operational state. That is, a suction amount at the high-pressure stage is the same between the first and second operational states, but a substantive suction amount at the low-pressure stage is smaller in the second operational state than in the first operational state.

[0415] As described above, in the present embodiment, refrigerant is not compressed in the second compression mechanism (120) in the second operational state. Thus, in the compressor (100) in which the four compression mechanisms (110-140) are mechanically connected to a single shaft, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Thus, the volume ratio of the compressor (100) is switched depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

<<Twelfth Embodiment of the Invention>>

[0416] A twelfth embodiment will be described with reference to FIGS. 43 and 44.

[0417] The present embodiment has a structure of a compressor (100) same as that of the seventh embodiment, and has a configuration of a refrigerant circuit (180) different from that of the seventh embodiment. Thus, only the refrigerant circuit (180) will be described below. Note that components of the refrigerant circuit (180) are the same as those of the seventh embodiment.

[0418] As illustrated in FIGS. 43 and 44, a low-pressure refrigerant pipe (181) connected to a gas-side end of an evaporator (103) is connected to a first suction pipe (182a). The first suction pipe (182a) is connected to a first suction port pipe (154-1) of a first compression mechanism (110). The low-pressure refrigerant pipe (181) branches into a connecting pipe (189i), and the connecting pipe (189i) is connected to a second port (P2) of a first three-way valve (107a). One end of a second section pipe (182b) is connected to a first port (P1) of the first three-way valve (107a), and the other end of the second section pipe (182b) is connected to a second suction port pipe (154-2) of a second compression mechanism (120).

[0419] A first discharge pipe (183a) is connected to a first discharge port pipe (155-1) of the compressor (100), and a second discharge pipe (183b) is connected to a second discharge port pipe (155-2). The first discharge pipe (183a) is connected to a first port (P1) of a second three-way valve (107b). One end of a connecting pipe (189j) is connected to a second port (P2) of the second three-way valve (107b), and the other end of the connecting pipe (189j) is connected to the second discharge pipe (183b). The second discharge pipe (183b) and the connecting pipe (189j) join together, and are connected to an intermediate-pressure refrigerant pipe (184). The intermediate-pressure refrigerant pipe (184) is connected to a refrigerant gas outlet (104a) of a gas-liquid separator (104).

[0420] A third port (P3) of the first three-way valve (107a) and a third port (P3) of the second three-way valve (107b) are connected together through a communication pipe (190).

[0421] The intermediate-pressure refrigerant pipe (184) branches into a branched pipe (185) downstream the refrigerant gas outlet (104a) of the gas-liquid separator (104). The branched pipe (185) further branches into a third suction pipe (182c) and a fourth suction pipe (182d). The third suction pipe (182c) is connected to a third suction port pipe (154-3) of a third compression mechanism (130), and the fourth suction pipe (182d) is connected to a fourth suction port pipe (154-4) of a fourth compression mechanism (140).

[0422] A third discharge port pipe (155-3) is connected to a refrigerant injection port (156) through a third discharge pipe (183c) and the high-pressure refrigerant injection pipe (186). The third discharge pipe (183c) and the high-pressure refrigerant injection pipe (186) form a single pipe.

[0423] A fourth discharge port pipe (155-4) of the compressor (100) is connected to one end of a high-pressure refrigerant pipe (187). The other end of the high-pressure refrigerant pipe (187) is connected to an inlet (104b) of the gas-liquid separator (104) through a gas cooler (102) and a first expansion valve (105). An outlet (104c) of the gas-liquid separator (104) is connected to a liquid-side end of the evaporator (103) through a liquid pipe (188) including a second expansion valve (106) in the middle thereof.

[0424] In the foregoing configuration, the branched pipe (185) serves as an injection mechanism through which intermediate-pressure refrigerant is injected to the compression mechanisms (110-140).

[0425] Each of the three-way valves (107a, 107b) is switchable between a first position in which the first port

(P1) and the second port (P2) are communicated with each other (see FIG. 43), and a second position in which the first port (P1) and the third port (P3) are communicated with each other (see FIG. 44).

[0426] The three-way valve (107a, 107b) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110-140). The three-way valve (107a, 107b) is configured so that, by changing a combination of four cylinder chambers (C1, C2, C3, C4) (switching the low-pressure compression mechanisms between connection in series and connection in parallel) in the refrigerant circuit (180), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0427] When the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the switching mechanism (107a, 107b) is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in parallel, and a state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in series.

[0428] The switching mechanism (volume ratio changing unit) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0429] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 43 and a second operational state illustrated in FIG. 44 depending on the change in operational conditions.

[0430] In the first operational state illustrated in FIG. 43, the first three-way valve (107a) and the second three-way valve (107b) are set to the first position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the second cylinder chamber (C2).

[0431] The intermediate-pressure refrigerant discharged from the first cylinder chamber (C1) flows into the connecting pipe (189j) through the first discharge pipe (183a) and the second three-way valve (107b). Then, such refrigerant is discharged from the second cylinder chamber (C2), and joins intermediate-pressure refrigerant flowing through the second discharge pipe (183b) in the intermediate-pressure refrigerant pipe (184). The refrigerant flowing through the intermediate-pressure refrigerant pipe (184) joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0432] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into a casing (150) of the compressor (100) through the third discharge pipe (183c), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from a discharge space (162) of a front head (157) to a space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0433] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to a low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

[0434] In the second operational state illustrated in FIG. 44, the first three-way valve (107a) and the second three-way valve (107b) are set to the second position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) is sucked into the first compression mechanism (110) through the low-pressure refrigerant pipe (181), the first suction pipe (182a), and the first suction port pipe (154-1). The refrigerant is compressed into first intermediate-pressure refrigerant in the first cylinder chamber (C1).

[0435] The first intermediate-pressure refrigerant is discharged from the first cylinder chamber (C1), and passes through the first discharge pipe (183a), the second three-way valve (107b), the communication pipe (190), the first three-way valve (107a), and the second section pipe (182b). Then, the first intermediate-pressure refrigerant is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into second intermediate-pressure refrigerant (intermediate-pressure refrigerant in a two-stage compression) in the second cylinder chamber (C2).

[0436] The second intermediate-pressure refrigerant discharged from the second cylinder chamber (C2) passes through the second discharge pipe (183b), and flows into the intermediate-pressure refrigerant pipe (184). Then, the second intermediate-pressure refrigerant joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). In the third compression mechanism (130) and the fourth compression mechanism (140), the refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0437] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into the casing (150) of the compressor (100) through the third discharge pipe (183c), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0438] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

Advantages of Twelfth Embodiment

[0439] According to the present embodiment, the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are used in parallel in the first operational state, and, on the other hand, are used in series in the second operational state. Thus, the suction volume at the low-pressure stage is smaller in the second operational state than in the first operational state. On the other hand, at the high-pressure stage, the third compression mechanism (130) and the fourth compression mechanism (140) are used in parallel in both of the first and second operational states, and the suction volume is not changed.

[0440] Consequently, the suction volume at the high-pressure stage is the same between the first and second operational states, whereas the suction volume at the low-pressure stage is smaller in the second operational state than in the first operational state. That is, a suction amount at the high-pressure stage is the same between the first and second operational states, but a substantive suction amount at the low-pressure stage is smaller in the second operational state than in the first operational state.

[0441] As described above, in the present embodiment, the two compression mechanisms (110, 120) at the low-pressure stage are used in parallel in the first operational state, and are used in series in the second operational state. Thus, in the compressor (100) in which the four compression mechanisms (110-140) are mechanically connected to a single shaft, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Thus, the volume ratio of the compressor (100) is switched depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

<<Thirteenth Embodiment of the Invention>>

[0442] A thirteenth embodiment will be described with reference to FIGS. 45 and 46.

[0443] The present embodiment has a structure of a compressor (100) same as that of the seventh embodiment, and has a configuration of a refrigerant circuit (180) different from that of the seventh embodiment. Thus, only the refrigerant circuit (180) will be described below. Note that components of the refrigerant circuit (180) are the same as those of the seventh embodiment.

[0444] As illustrated in FIGS. 45 and 46, a low-pressure refrigerant pipe (181) connected to a gas-side end of an evaporator (103) branches into a first suction pipe (182a) and a second section pipe (182b). The first suction pipe (182a) is connected to a first suction port pipe (154-1) of a first compression mechanism (110), and the second section pipe (182b) is connected to a second suction port pipe (154-2) of a second compression mechanism (120).

[0445] A first discharge pipe (183a) is connected to a first discharge port pipe (155-1) of the compressor (100), and a second discharge pipe (183b) is connected to a second discharge port pipe (155-2). The first discharge pipe (183a) and the second discharge pipe (183b) join together, and are connected to an intermediate-pressure refrigerant pipe (184). The intermediate-pressure refrigerant pipe (184) is connected to a refrigerant gas outlet (104a) of a gas-liquid separator (104).

[0446] The intermediate-pressure refrigerant pipe (184) branches into a branched pipe (185) downstream the refrigerant gas outlet (104a) of the gas-liquid separator (104). The branched pipe (185) is connected to a third suction port pipe (154-3) of a third compression mechanism (130) through a third suction pipe (182c). The branched pipe (185) branches into a connecting pipe (189k) in the middle thereof, and the connecting pipe (189k) is connected to a second port (P2) of a first three-way valve (107a). One end of a fourth suction pipe (182d) is connected to a first port (P1) of the first three-way valve (107a), and the other end of the fourth suction pipe (182d) is connected to a fourth suction port pipe (154-4) of a fourth compression mechanism (140).

[0447] One end of a third discharge pipe (183c) is connected to a third discharge port pipe (155-3), and the other end of the third discharge pipe (183c) is connected to a first port (P1) of a second three-way valve (107b). A second port (P2) of the second three-way valve (107b) is connected to a refrigerant injection port (156) through a high-pressure refrigerant injection pipe (186).

[0448] A third port (P3) of the first three-way valve (107a) and a third port (P3) of the second three-way valve (107b) are connected together through a communication pipe (190).

[0449] A fourth discharge port pipe (155-4) of the compressor (100) is connected to one end of a high-pressure refrigerant pipe (187). The other end of the high-pressure refrigerant pipe (187) is connected to an inlet (104b) of the gas-liquid separator (104) through a gas cooler (102) and a first expansion valve (105). An outlet (104c) of the gas-liquid separator (104) is connected to a liquid-side end of the evaporator (103) through a liquid pipe (188) including a second expansion valve (106) in the middle thereof.

[0450] In the foregoing configuration, the branched pipe (185) serves as an injection mechanism through which intermediate-pressure refrigerant is injected to the compression mechanisms (110-140).

[0451] Each of the three-way valves (107a, 107b) is switchable between a first position in which the first port (P1) and the second port (P2) are communicated with each other (see FIG. 45), and a second position in which the first port (P1) and the third port (P3) are communicated with each other (see FIG. 46).

[0452] The three-way valve (107a, 107b) serves as a switching mechanism (volume ratio changing unit) configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110-140). The three-way valve (107a, 107b) is configured so that, by changing a combination of four cylinder chambers (C1, C2, C3, C4) (switching the high-pressure compression mechanisms between connection in series and connection in parallel) in the refrigerant circuit (180), a ratio of a suction volume of the low-pressure compression mechanism to a suction volume of the high-pressure compression mechanism is changed.

[0453] When the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the switching mechanism (107a, 107b) is switchable between a state illustrated in FIG. 45, in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in parallel; and a state illustrated in FIG. 46, in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in series.

[0454] The switching mechanism (volume ratio changing unit) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

Operation

[0455] In an air conditioning apparatus, it is switchable between a first operational state illustrated in FIG. 45 and a second operational state illustrated in FIG. 46 depending on the change in operational conditions.

[0456] In the first operational state illustrated in FIG. 45, the first three-way valve (107a) and the second three-way valve (107b) are set to the first position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into intermediate-pressure refrigerant in the first cylinder chamber (C1) and the second cylinder chamber (C2).

[0457] The intermediate-pressure refrigerant which is discharged from the first cylinder chamber (C1) through the first discharge port pipe (155-1) and flows into the first discharge pipe (183a), and the intermediate-pressure refrigerant which is discharged from the second cylinder chamber (C2) through the second discharge port pipe (155-2) and flows into the second discharge pipe (183b) join together in the intermediate-pressure refrigerant pipe (184).

[0458] The refrigerant flowing through the intermediate-pressure refrigerant pipe (184) joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) branches into the third suction pipe (182c) and the fourth suction pipe (182d). The intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and the intermediate-pressure refrigerant from the fourth suction pipe (182d) is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the third cylinder chamber (C3) and the fourth cylinder chamber (C4).

[0459] The high-pressure refrigerant discharged through the third discharge port pipe (155-3) is injected into a casing (150) of the compressor (100) through the third discharge pipe (183c), the high-pressure refrigerant injection pipe (186), and the refrigerant injection port (156). The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from a discharge space (162) of a front head (157) to a space inside the casing (150). Thus, the high-pressure refrigerant compressed in the third cylinder chamber (C3) and the high-pressure refrigerant compressed in the fourth cylinder chamber (C4) join together in the casing (150).

[0460] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to an intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to a low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130) and the fourth compression mechanism (140).

[0461] In the second operational state illustrated in FIG. 46, the first three-way valve (107a) and the second three-way valve (107b) are set to the second position. When starting the compressor (100) in such a state, low-pressure gas refrigerant evaporated by exchanging heat with air in the evaporator (103) branches into the first suction pipe (182a) and the second section pipe (182b) from the low-pressure refrigerant pipe (181). The refrigerant from the first suction pipe (182a) is sucked into the first compression mechanism (110) through the first suction port pipe (154-1), and the refrigerant from the second section pipe (182b) is sucked into the second compression mechanism (120) through the second suction port pipe (154-2). The refrigerant is compressed into first intermediate-pressure refrigerant (intermediate-pressure refrigerant in a two-stage compression) in the first cylinder chamber (C1) and the second cylinder chamber (C2).

[0462] The intermediate-pressure refrigerant which is discharged from the first cylinder chamber (C1) through the first discharge port pipe (155-1) and flows into the first discharge pipe (183a), and the intermediate-pressure refrigerant which is discharged from the second cylinder chamber (C2) through the second discharge port pipe (155-2) and flows into the second discharge pipe (183b) join together in the intermediate-pressure refrigerant pipe (184).

[0463] The refrigerant flowing through the intermediate-pressure refrigerant pipe (184) joins intermediate-pressure refrigerant from the gas-liquid separator (104), and flows into the branched pipe (185). The intermediate-pressure refrigerant flowing through the branched pipe (185) flows into the third suction pipe (182c). The first intermediate-pressure refrigerant from the third suction pipe (182c) is sucked into the third compression mechanism (130) through the third suction port pipe (154-3), and is compressed into second intermediate-pressure refrigerant in the third cylinder chamber (C3).

[0464] The second intermediate-pressure refrigerant discharged from the third cylinder chamber (C3) flows through the third discharge port pipe (155-3), the third discharge pipe (183c), the second three-way valve (107b), the communication pipe (190), and the fourth suction pipe (182d) in this order. The second intermediate-pressure refrigerant is sucked into the fourth compression mechanism (140) through the fourth suction port pipe (154-4). Then, the refrigerant is compressed into high-pressure refrigerant in the fourth cylinder chamber (C4). The high-pressure refrigerant compressed in the fourth cylinder chamber (C4) flows out from the discharge space (162) of the front head (157) to the space inside the casing (150).

[0465] The high-pressure refrigerant in the casing (150) is discharged from the casing (150) through the fourth discharge port pipe (155-4), and flows into the gas cooler (102) through the high-pressure refrigerant pipe (fourth discharge pipe) (187). After the refrigerant dissipates heat to outdoor air in the gas cooler (102), the pressure of the refrigerant is decreased to the intermediate pressure level by the first expansion valve (105), and such refrigerant flows into the gas-liquid separator (104). The refrigerant is separated into gas and liquid in the gas-liquid separator (104), and the liquid refrigerant flows out from the gas-liquid separator (104). After the pressure of the liquid refrigerant is decreased to the low pressure level by the second expansion valve (106), such refrigerant is evaporated in the evaporator (103), and is sucked into the first compression mechanism (110) and the second compression mechanism (120). The gas refrigerant in the gas-liquid separator (104) is injected to the third compression mechanism (130).

Advantages of Thirteenth Embodiment

[0466] According to the present embodiment, the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are used in parallel in the first operational state, and, on the other hand, are used in series in the second operational state. Thus, the suction volume at the high-pressure stage is smaller in the second operational state than in the first operational state. On the other hand, at the low-pressure stage, the first compression mechanism (110) and the second compression mechanism (120) are used in parallel in both of the first and second operational states, and the suction volume is not changed.

[0467] Consequently, the suction volume at the low-pressure stage is the same between the first and second operational states, whereas the suction volume at the high-pressure stage is smaller in the second operational state than in the first operational state. That is, a suction amount at the low-pressure stage is the same between the first and second operational states, but a substantive suction amount at the high-pressure stage is smaller in the second operational state than in the first operational state.

[0468] As described above, in the present embodiment, the two compression mechanisms (130, 140) at the high-pressure stage are used in parallel in the first operational state, and are used in series in the second operational state. Thus, in the compressor (100) in which the four compression mechanisms (110-140) are mechanically connected to a single shaft, the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism in the first and second operational states can be adjusted. Thus, the volume ratio of the compressor (100) is switched depending on the operational conditions while performing an operation with high COP (coefficient of performance). In addition, a torque variation due to the compression of refrigerant can be adjusted.

<<Other Embodiments>>

[0469] The foregoing embodiments may have the following configurations.

[0470] In the foregoing embodiments, the volumes of the four cylinder chambers are different from each other. However, in the first to sixth embodiments, the four cylinder chambers may be set to at least two suction volume levels. In such a case, the volume of the outer cylinder chamber (C1) of the first compression mechanism (20) is the same as that of the outer cylinder chamber (C3) of the second compression mechanism (30), and the volume of the inner cylinder chamber (C2) of the first compression mechanism (20) is the same as that of the inner cylinder chamber (C4) of the second compression mechanism (30). Even in such a state, it is switchable between the first operational state in which two cylinder chambers of the compression mechanisms (20, 30) are used in parallel, and the second operational state in which the two cylinder chambers are used in series, or a combination of high-pressure and low-pressure cylinder chambers (C1, C2, C3, C4) is changed. Thus, the volume ratio of the compressor (1) can be changed depending on the operational conditions.

[0471] In the seventh to thirteenth embodiments, the volumes of the cylinder chambers (C1-C4) may be the same except for the ninth embodiment.

[0472] In the present invention, the configuration of the compressor may be changed to any configurations as long as the compressor including the four cylinder chambers is used in the refrigerating apparatus. For example, in the seventh to thirteenth embodiments, a rolling piston compressor may be used, in which a blade and a piston are separated.

[0473] The three-way valve (7) is used in the first, second, fourth, and fifth embodiments, and the four-way valve (8) is used in the third embodiment. However, a plurality of opening/closing valves (solenoid valves) may be combined and used.

[0474] As illustrated in FIGS. 47 and 48, an internal pressure of the casing (10) may be at any of low, high, and intermediate pressure levels. The refrigerant circuit may be configured as necessary, thereby freely changing a setting of the internal pressure.

[0475] In the foregoing embodiments, refrigerant filling the refrigerant circuit (60, 180) may be refrigerant other than carbon dioxide (e.g., Freon refrigerant).

[0476] In the foregoing embodiments, the injection pipe (68, 185) is used as a cooling unit configured to cool refrigerant at an intermediate-pressure stage of the compressor (1, 100), but a heat exchanger (intermediate cooler) may be used as the cooling unit.

[0477] In the foregoing embodiments, the air conditioning apparatus performing the cooling operation has been described, but a target to which the present invention is applied is not limited to a unit only for cooling.

(Examples of Combination of Suction and Discharge Port Pipes in First to Sixth Embodiments)

[0478] In the first to sixth embodiments, the first suction port pipe (14-1), the first discharge port pipe (15-1), the second suction port pipe (14-2), and the second discharge port pipe (15-2) may have the following configurations as illustrated in, e.g., FIGS. 49-62.

[0479] In a first variation illustrated in FIG. 49, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4).

[0480] In a second variation illustrated in FIG. 50, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4).

[0481] In a third variation illustrated in FIG. 51, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4).

[0482] In a fourth variation illustrated in FIG. 52, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0483] In a fifth variation illustrated in FIG. 53, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0484] In a sixth variation illustrated in FIG. 54, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber

(C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0485] In a seventh variation illustrated in FIG. 55, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0486] In an eighth variation illustrated in FIG. 56, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0487] In a ninth variation illustrated in FIG. 57, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4).

[0488] In a tenth variation illustrated in FIG. 58, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0489] In an eleventh variation illustrated in FIG. 59, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) includes a second discharge port a-pipe (15-2a) through which refrigerant is discharged from the second outer cylinder chamber (C3), and a second discharge port b-pipe (15-2b) through which refrigerant is discharged from the second inner cylinder chamber (C4).

[0490] In a twelfth variation illustrated in FIG. 60, a first suction port pipe (14-1) is a single suction port pipe through which refrigerant is sucked into both of a first outer cylinder chamber (C1) and a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4).

[0491] In a thirteenth variation illustrated in FIG. 61, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) includes a first discharge port a-pipe (15-1a) through which refrigerant is discharged from the first outer cylinder chamber (C1), and a first discharge port b-pipe (15-1b) through which refrigerant is discharged from the first inner cylinder chamber (C2). A second suction port pipe (14-2) is a single suction port pipe through which refrigerant is sucked into both of a second outer cylinder chamber (C3) and a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4).

[0492] In a fourteenth variation illustrated in FIG. 62, a first suction port pipe (14-1) includes a first suction port a-pipe (14-1a) through which refrigerant is sucked into a first outer cylinder chamber (C1), and a first suction port b-pipe (14-1b) through which refrigerant is sucked into a first inner cylinder chamber (C2). A first discharge port pipe (15-1) is a single discharge port pipe through which refrigerant is discharged from both of the first outer cylinder chamber (C1) and the first inner cylinder chamber (C2). A second suction port pipe (14-2) includes a second suction port a-pipe (14-2a) through which refrigerant is sucked into a second outer cylinder chamber (C3), and a second suction port b-pipe (14-2b) through which refrigerant is sucked into a second inner cylinder chamber (C4). A second discharge port pipe (15-2) is a single discharge port pipe through which refrigerant is discharged from both of the second outer cylinder chamber (C3) and the second inner cylinder chamber (C4).

[0493] As described above, the suction and discharge port pipes can be used in various combinations. Such combinations are arbitrarily selected, thereby adjusting the volume ratio.

[0494] The foregoing embodiments have been set forth merely for purposes of preferred examples in nature, and are not intended to limit the scope, applications, and use of the invention.

INDUSTRIAL APPLICABILITY

[0495] As described above, the present invention is useful for the refrigerating apparatus for the two-stage compression refrigerant cycle.

DESCRIPTION OF REFERENCE CHARACTERS

[0496]

1	Compressor
7	Three-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
7a	First Three-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
7b	Second Three-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
8a	First Four-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
8b	Second Four-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
20	First Compression Mechanism
21	First Cylinder
22	First Circular Piston
30	Second Compression Mechanism
31	Second Cylinder
32	Second Circular Piston
53	Drive Shaft
100	Compressor
110	First Compression Mechanism
120	Second Compression Mechanism
130	Third Compression Mechanism
140	Fourth Compression Mechanism
111	Cylinder
112	Cylinder
113	Cylinder
114	Cylinder
112	Eccentric Piston
122	Eccentric Piston
132	Eccentric Piston
142	Eccentric Piston
107	Three-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
107a	First Three-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
107b	Second Three-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
108a	First Four-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
108b	Second Four-Way Valve (Volume Ratio Changing Unit, Switching Mechanism)
C1	First Outer Cylinder Chamber
C2	First Inner Cylinder Chamber
C3	Second Outer Cylinder Chamber
C4	Second Inner Cylinder Chamber

Claims

1. A refrigerating apparatus in which a two-stage compression refrigeration cycle is performed, comprising:

a refrigerant circuit (60), (180) connected to a compressor (1), (100) in which a plurality of compression mechanisms (20, 30), (110, 120, 130, 140) are mechanically connected together through a single drive shaft (53), (173);
four cylinder chambers (C1, C2, C3, C4) in the

compression mechanisms (20, 30), (110, 120, 130, 140); and
volume ratio changing units (7, 8), (107, 108) configured to change a ratio of a suction volume of a low-pressure compression mechanism to a suction volume of a high-pressure compression mechanism.

2. The refrigerating apparatus of claim 1, wherein the volume ratio changing unit (7, 8), (107, 108) is configured to change the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism by changing a combination of the four cylinder chambers (C1, C2, C3, C4).

3. The refrigerating apparatus of claim 1, wherein the plurality of compression mechanisms (20, 30) are a first compression mechanism (20) and a second compression mechanism (30), each of which includes two cylinder chambers (C1, C2), (C3, C4), and
each of the compression mechanisms (20, 30) includes a cylinder (21, 31) with a circular cylinder space and a circular eccentric piston (22, 32) eccentrically rotating in the cylinder space, an inner cylinder chamber (C2, C4) is formed on an inner circumferential side of the circular eccentric piston (22, 32) in the cylinder space, and an outer cylinder chamber (C1, C3) is formed on an outer circumferential side of the circular eccentric piston (22, 32).

4. The refrigerating apparatus of claim 3, wherein the four cylinder chambers (C1, C2, C3, C4) are set to at least two suction volume levels.

5. The refrigerating apparatus of claim 3, wherein suction volumes of the four cylinder chambers (C1, C2, C3, C4) are different from each other.

6. The refrigerating apparatus of claim 3, wherein, when the first compression mechanism (20) is at the low-pressure stage and the second compression mechanism (30) is at the high-pressure stage, the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected together in parallel, and a state in which the inner cylinder chamber (C4) and the outer cylinder chamber (C3) of the second compression mechanism (30) are connected together in series.

7. The refrigerating apparatus of claim 3, wherein the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) and one of the cylinder chambers (C4) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C3) of the second compression mechanism (30) is used as the high-pressure compression mechanism.

8. The refrigerating apparatus of claim 3, wherein the volume ratio changing unit (8) is a switching mechanism which is switchable between a state in which both of the cylinder chambers (C1, C2) of the first compression mechanism (20) are used as the low-pressure compression mechanism, and both of the cylinder chambers (C3, C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism, and a state in which one of the cylinder chambers (C1) of the first compression mechanism (20) and one of the cylinder chambers (C3) of the second compression mechanism (30) are used as the low-pressure compression mechanism, and the other cylinder chamber (C2) of the first compression mechanism (20) and the other cylinder chamber (C4) of the second compression mechanism (30) are used as the high-pressure compression mechanism.

9. The refrigerating apparatus of claim 3, wherein, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which refrigerant is compressed in both of the cylinder chambers (C3, C4) of the second compression mechanism (30) to provide a difference between a suction pressure and a discharge pressure, and a state in which refrigerant is compressed in one of the cylinder chambers (C3), (C4) of the second compression mechanism (30) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other cylinder chamber (C4), (C3) allow uncompressed refrigerant to pass through the other cylinder chamber (C4), (C3).

10. The refrigerating apparatus of claim 3, wherein, when the first compression mechanism (20) is at the low-pressure stage, and the second compression mechanism (30) is at the high-pressure stage, the volume ratio changing unit (7) is a switching mechanism which is switchable between a state in which

refrigerant is compressed in both of the cylinder chambers (C1, C2) of the first compression mechanism (20) to provide a difference between a suction pressure and a discharge pressure, and a state in which refrigerant is compressed in one of the cylinder chambers (C1), (C2) of the first compression mechanism (20) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other cylinder chamber (C2), (C1) allow uncompressed refrigerant to pass through the other cylinder chamber (C2), (C1).

11. The refrigerating apparatus of claim 1, wherein the switching mechanism (7, 8) is a switching valve configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (20, 30).

12. The refrigerating apparatus of claim 1, wherein the volume ratio changing unit (7, 8) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

13. The refrigerating apparatus of claim 1, wherein the plurality of compression mechanisms (110, 120, 130, 140) are a first compression mechanism (110), a second compression mechanism (120), a third compression mechanism (130), and a fourth compression mechanism (140), each of which includes a single cylinder chamber, and
each of the compression mechanisms (110, 120, 130, 140) includes a cylinder (111, 121, 131, 141) with a circular cylinder space and an eccentric piston (112, 122, 132, 142) eccentrically rotating in the cylinder space.

14. The refrigerating apparatus of claim 13, wherein the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and a state in which the first compression mechanism (110), the second compression mechanism (120), and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the fourth compression mechanism (140) is used as the high-pressure compression mechanism.

15. The refrigerating apparatus of claim 13, wherein the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and a state in which the first compression mechanism (110) is used as the low-pressure compression mechanism, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are used as the high-pressure compression mechanism.

16. The refrigerating apparatus of claim 13, wherein a cylinder volume of at least one of the compression mechanisms is different from cylinder volumes of the other compression mechanisms, and
the volume ratio changing unit (108) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) are used as the low-pressure compression mechanism, and the third compression mechanism (130) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism, and a state in which the first compression mechanism (110) and the third compression mechanism (130) are used as the low-pressure compression mechanism, and the second compression mechanism (120) and the fourth compression mechanism (140) are used as the high-pressure compression mechanism.

17. The refrigerating apparatus of claim 13, wherein, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which refrigerant is compressed in both of the third compression mechanism (130) and the fourth compression mechanism (140) to provide a difference between a suction pressure and a discharge pressure, and a state in which refrigerant is compressed in one of the third compression mechanism (130) and the fourth compression mechanism (140) to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in the other compression mechanism allow uncompressed refrigerant to pass through the other compression mechanism.

18. The refrigerating apparatus of claim 13, wherein the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in both of the low-pressure and high-pressure compression mechanisms to provide a difference between a suction pressure and a discharge pressure, and a state in which, when the first compression mechanism (110) is at the low-pressure stage, and the second compression mechanism (120), the third compression mechanism (130), and the fourth compression mechanism (140) are at the high-pressure stage, refrigerant is compressed in the low-pressure compression mechanism to provide the difference between the suction pressure and the discharge pressure, and, on the other hand, the substantially same suction and discharge pressures in one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140) at the high-pressure stage allow uncompressed refrigerant to pass through the one of the second compression mechanism (120), the third compression mechanism (130), or the fourth compression mechanism (140).

19. The refrigerating apparatus of claim 13, wherein, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in parallel, and a state in which the first compression mechanism (110) and the second compression mechanism (120) at the low-pressure stage are connected together in series.

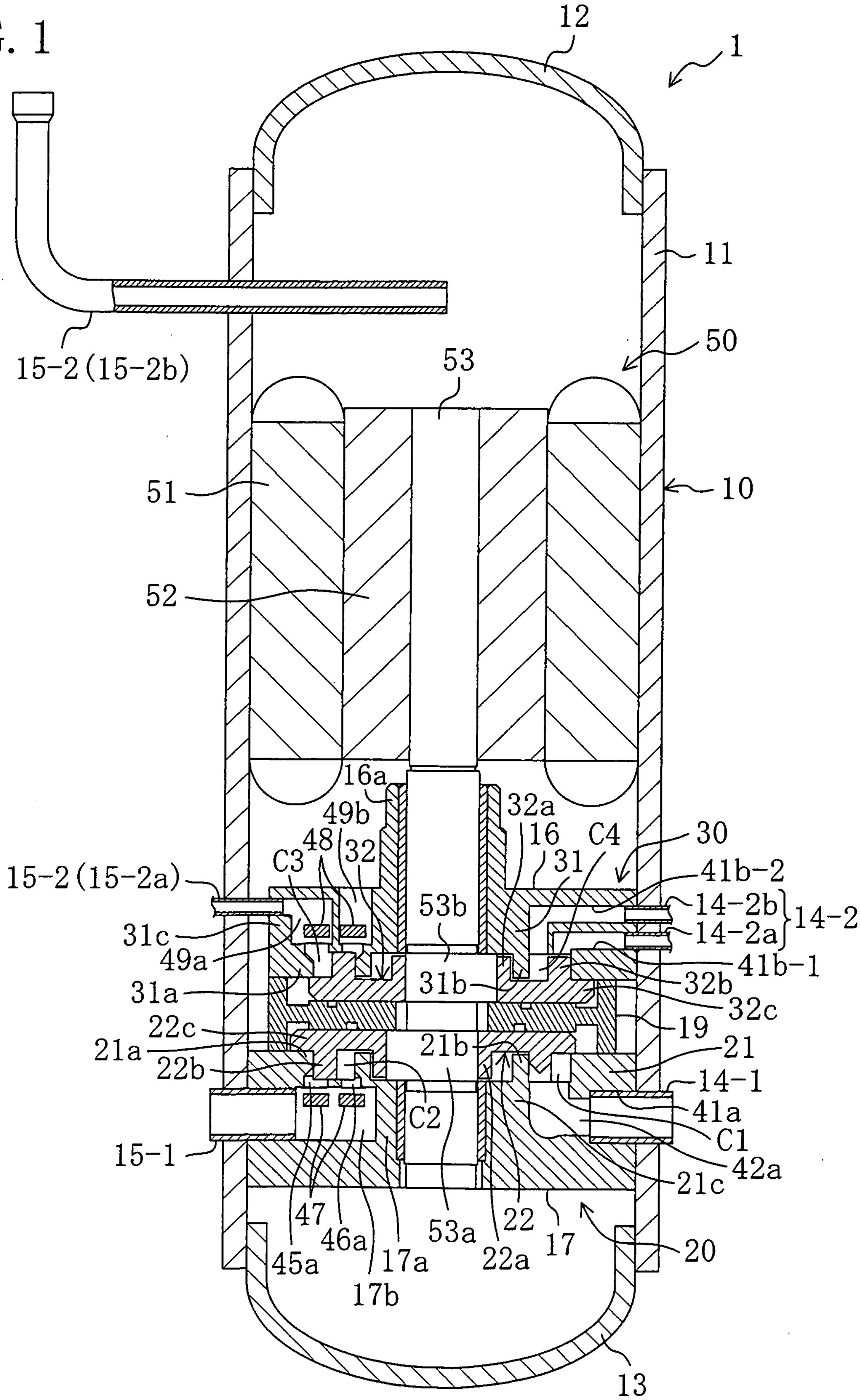
20. The refrigerating apparatus of claim 13, wherein, when the first compression mechanism (110) and the second compression mechanism (120) are at the low-pressure stage, and the third compression mechanism (130) and the fourth compression mechanism (140) are at the high-pressure stage, the volume ratio changing unit (107) is a switching mechanism which is switchable between a state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in parallel, and a state in which the third compression mechanism (130) and the fourth compression mechanism (140) at the high-pressure stage are connected together in series.

21. The refrigerating apparatus of claim 13, wherein the switching mechanism (107, 108) is a switching valve configured to switch a flow path of low-pressure, intermediate-pressure, or high-pressure refrigerant into each of the compression mechanisms (110, 120, 130, 140).

22. The refrigerating apparatus of claim 13, wherein the volume ratio changing unit (107) changes the ratio of the suction volume of the low-pressure compression mechanism to the suction volume of the high-pressure compression mechanism depending on a change in operational conditions.

23. The refrigerating apparatus of claim 1, wherein refrigerant is carbon dioxide.

FIG. 1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C3
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53b
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14-2
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32b
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32c
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22c
21b
21
21a
22b
14-1
41a
C2
C1
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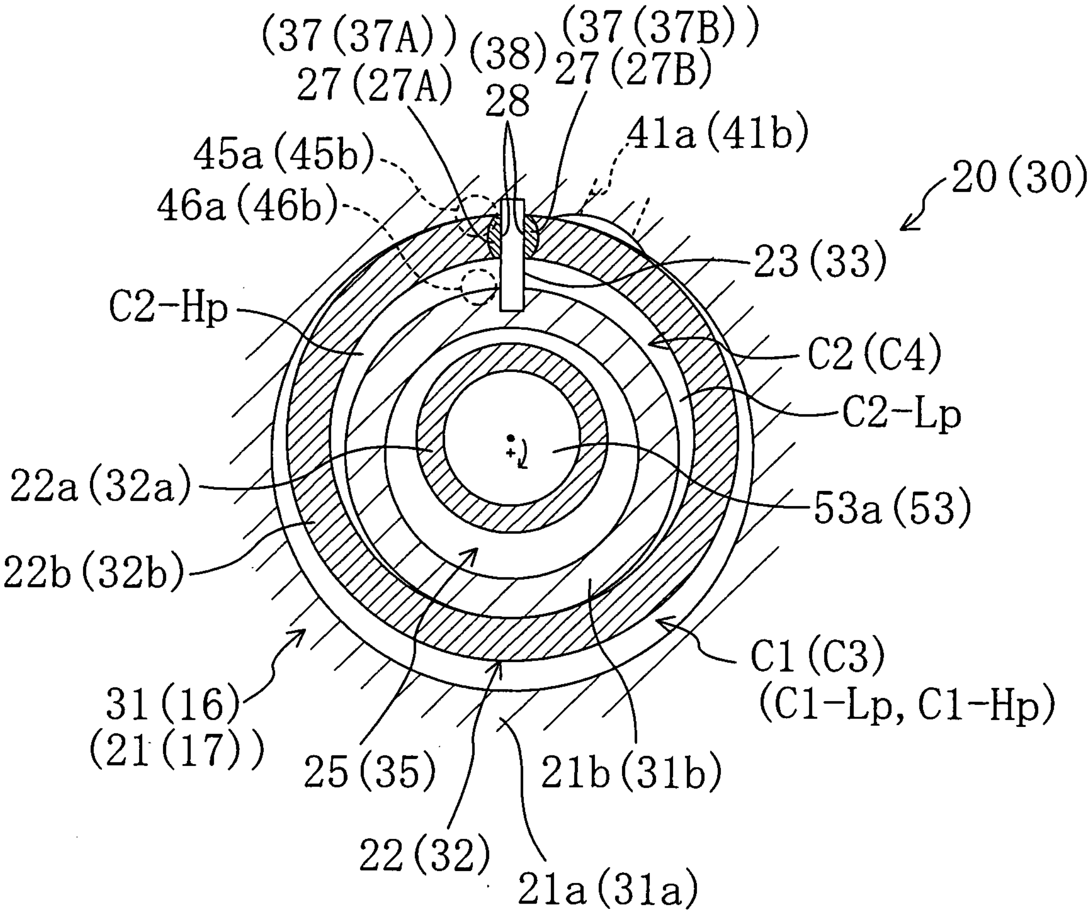
17a
22a
20
17b
13

FIG. 2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23(33)
C2-Hp
C2(C4)
C2-Lp
22a(32a)
53a(53)
22b(32b)
C1(C3)
(C1-Lp, C1-Hp)
31(16)
(21(17))
25(35)
21b(31b)
22(32)
21a(31a)

FIG. 3

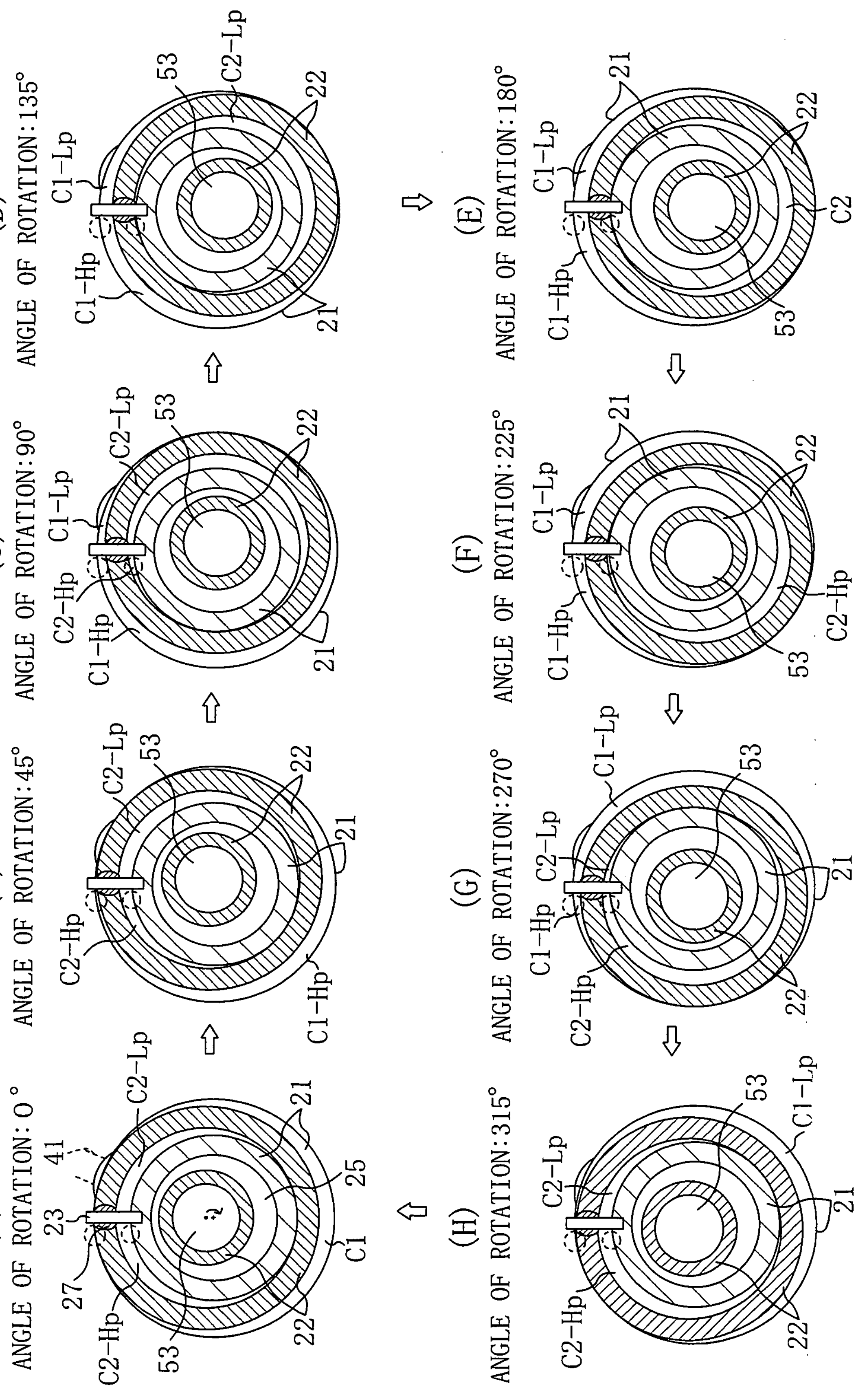

(A)
ANGLE OF ROTATION: 0 °
(B)
ANGLE OF ROTATION:45°
(C)
ANGLE OF ROTATION:90°
(D)
ANGLE OF ROTATION:135°
(E)
ANGLE OF ROTATION:180°
(F)
ANGLE OF ROTATION:225°
(G)
ANGLE OF ROTATION:270°
(H)
ANGLE OF ROTATION:315°
C1-Hp
C1-Lp
C2-Hp
C2-Lp
C1
C2
21
22
23
25
27
41
53

FIG. 4

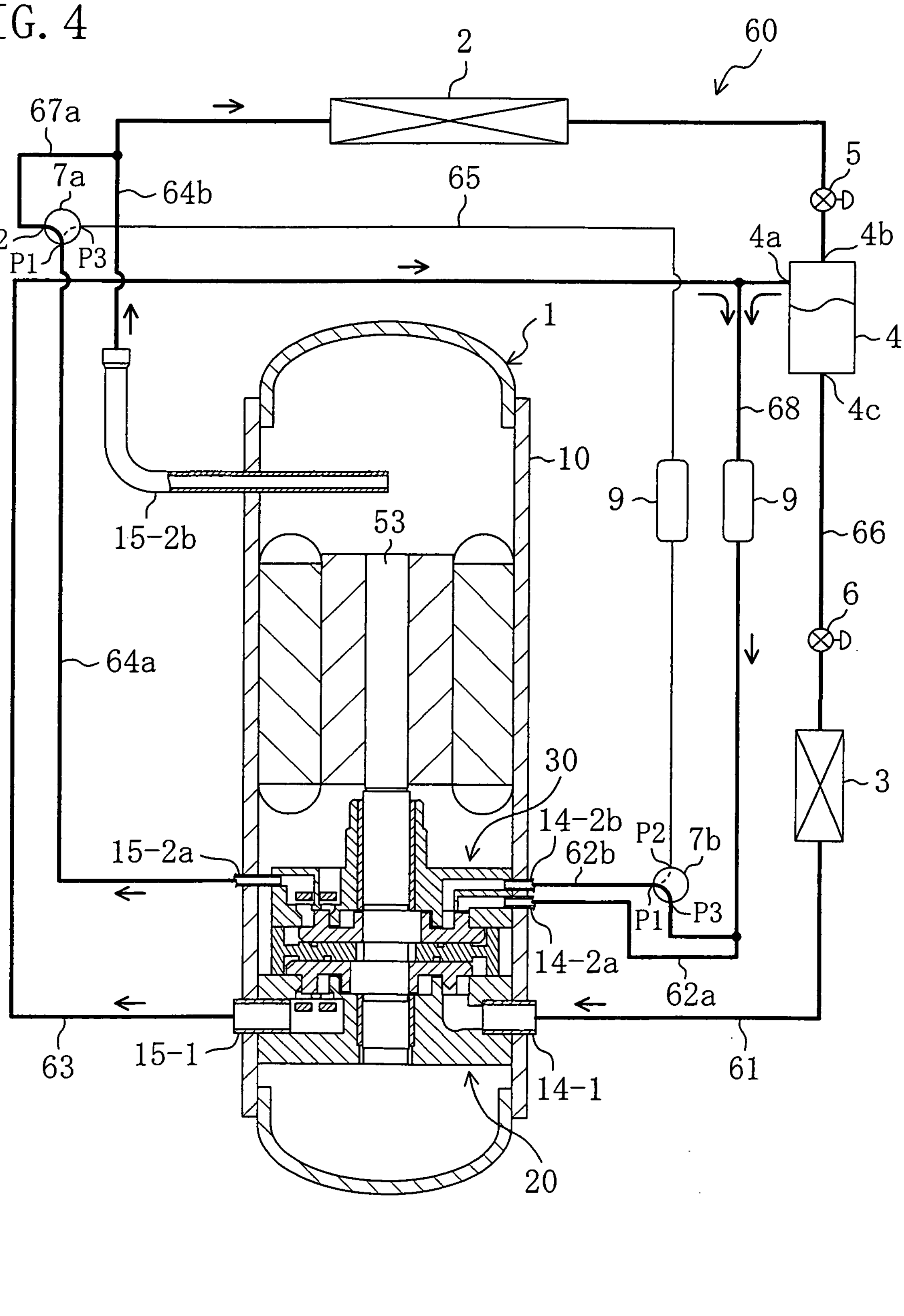
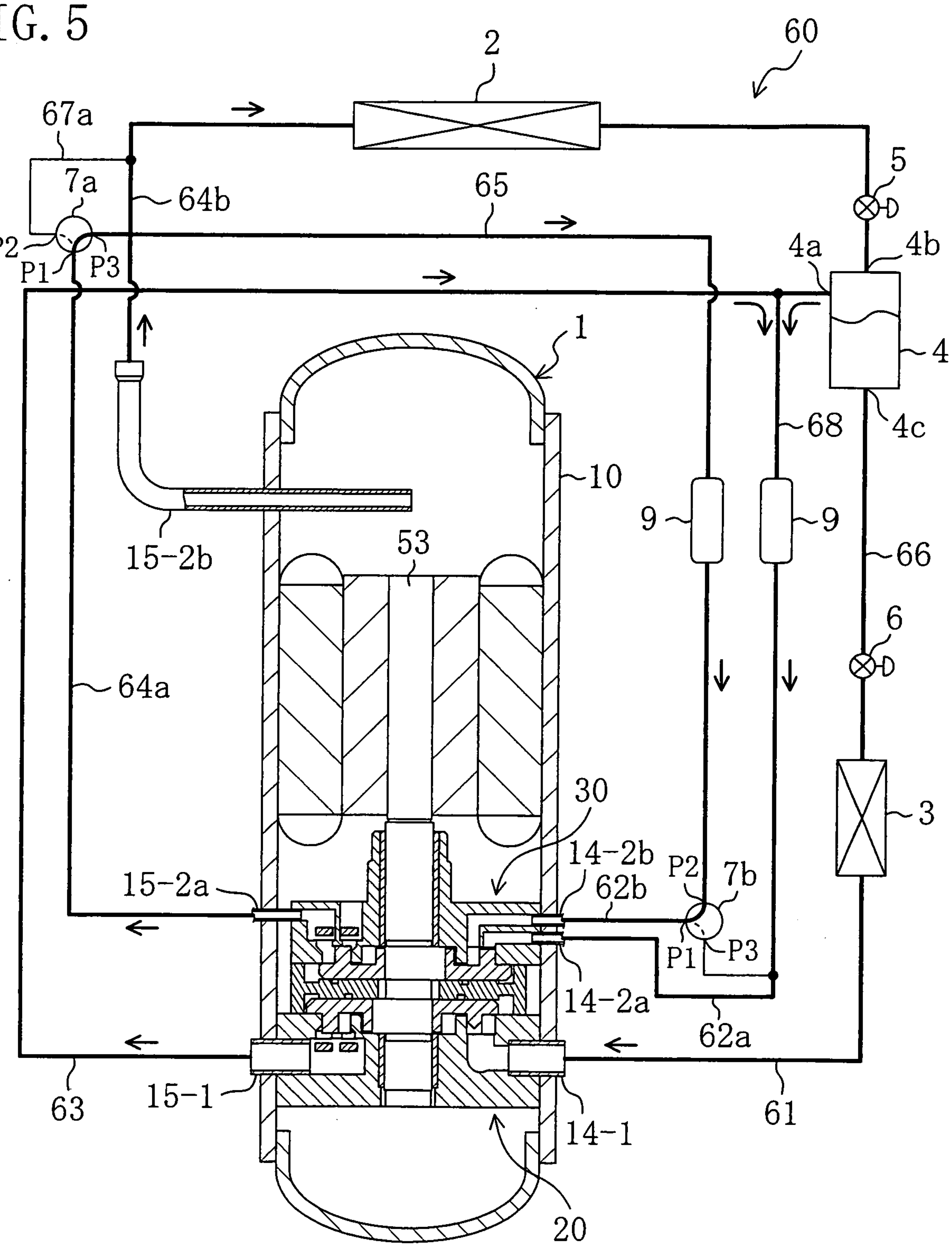

2
60
67a
7a
64b
65
5
4a
4b
P2
P1
P3
1
4
68
4c
10
9
9
15-2b
53
66
6
64a
3
30
14-2b
P2
7b
15-2a
62b
P1
P3
14-2a
62a
63
15-1
14-1
61
20

FIG. 5


2
60
67a
7a
64b
65
5
4a
4b
P2
P1
P3
1
4
68
4c
10
9
9
66
15-2b
53
6
64a
3
30
14-2b
15-2a
62b
P2
7b
P1
P3
14-2a
62a
63
15-1
14-1
61
20

IP:INTERMEDIATE PRESSURE REFRIGERANT
LP:LOW PRESSURE REFRIGERANT
HP:HIGH PRESSURE REFRIGERANT

FIG. 6

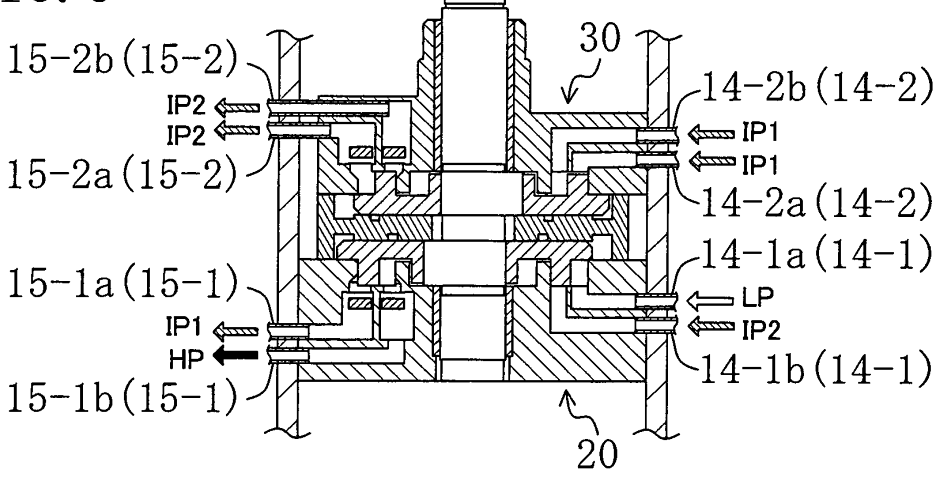


FIG. 7

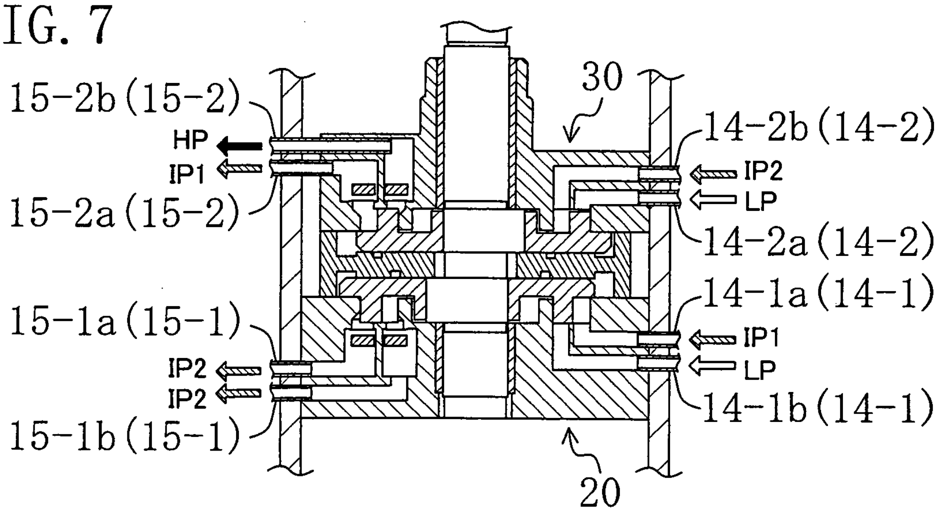


FIG. 8

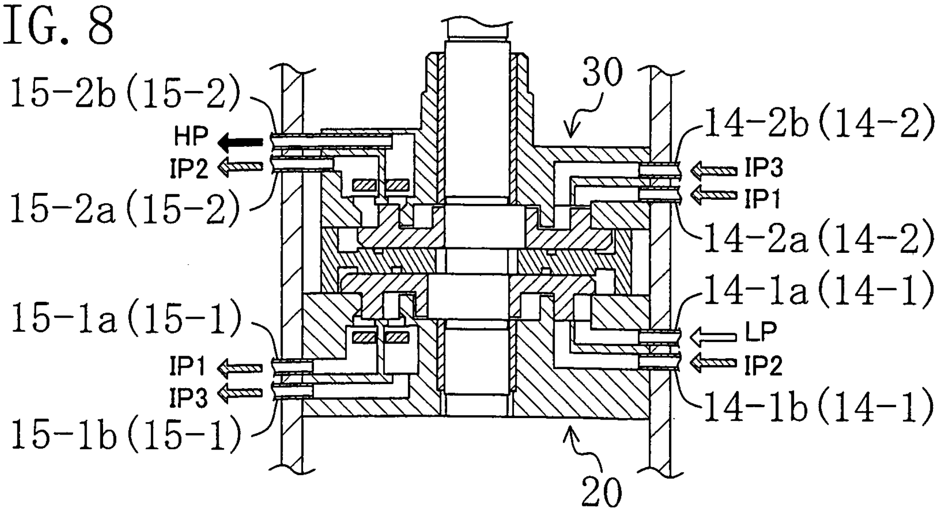


FIG. 9

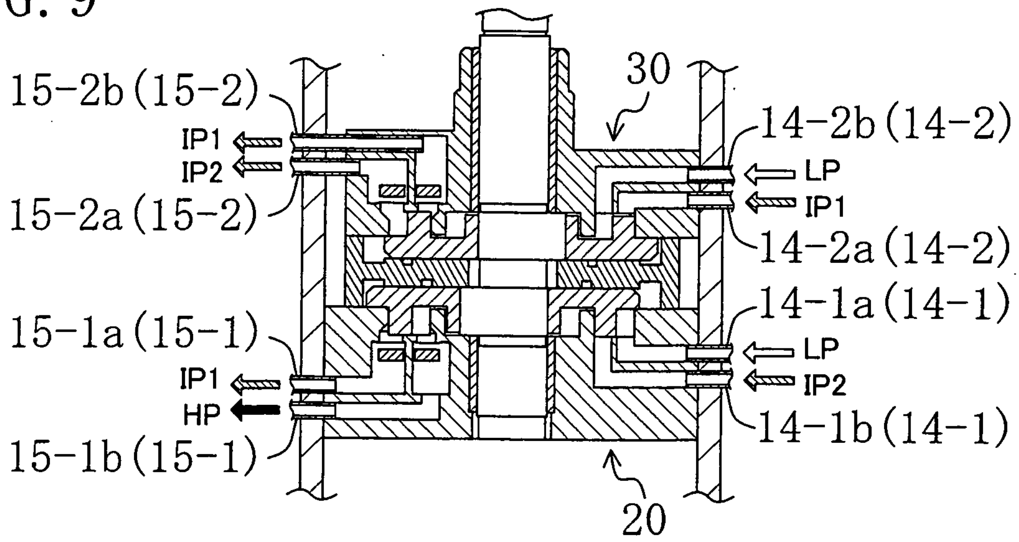

15-2b(15-2)
IP1
IP2
15-2a(15-2)
15-1a(15-1)
IP1
HP
15-1b(15-1)
30
14-2b(14-2)
LP
IP1
14-2a(14-2)
14-1a(14-1)
LP
IP2
14-1b(14-1)
20

FIG. 10

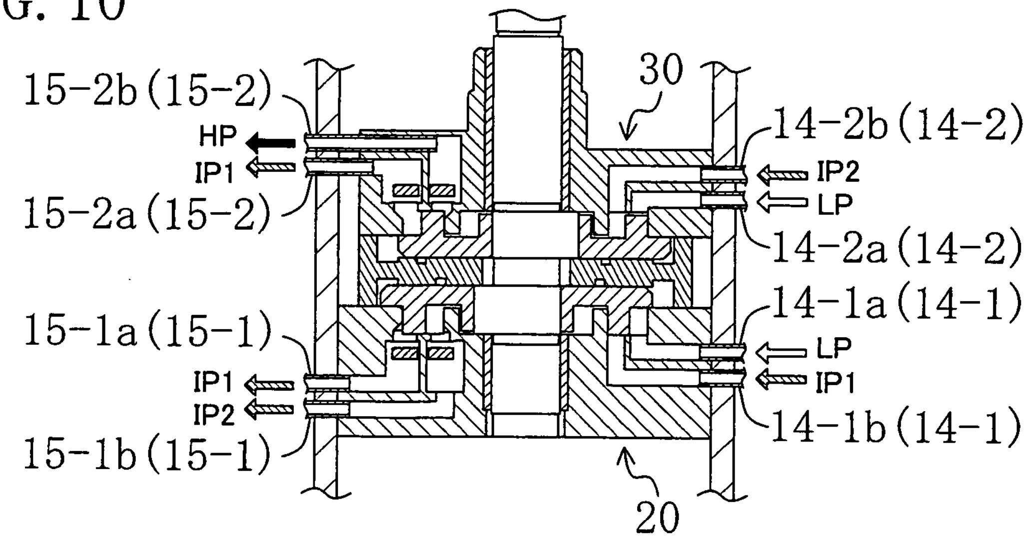
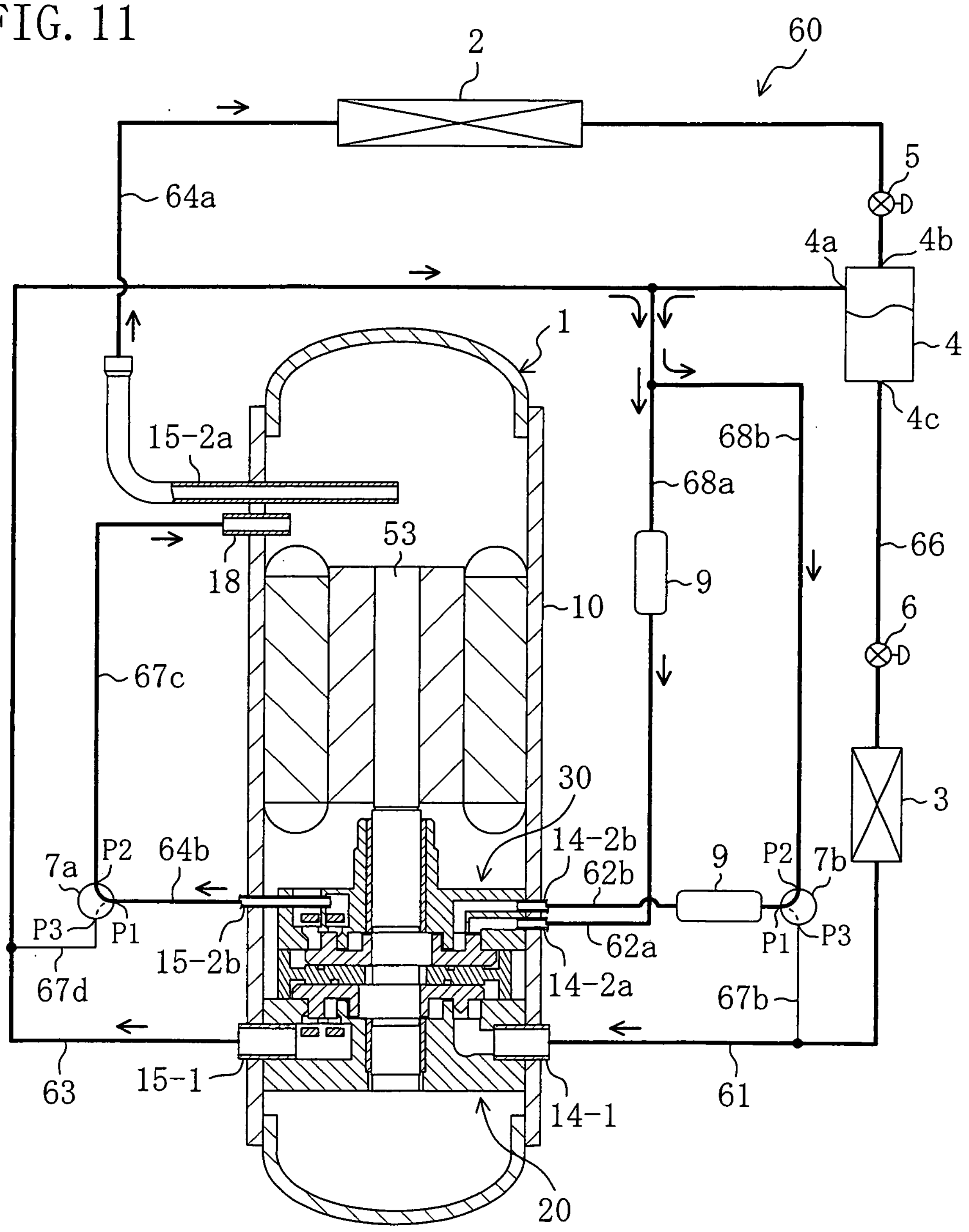

15-2b(15-2)
HP
IP1
15-2a(15-2)
15-1a(15-1)
IP1
IP2
15-1b(15-1)
30
14-2b(14-2)
IP2
LP
14-2a(14-2)
14-1a(14-1)
LP
IP1
14-1b(14-1)
20

FIG. 11



60
2
5
4a
4b
4
4c
64a
1
15-2a
68b
68a
66
18
53
9
10
6
67c
30
3
14-2b
62b
9
P2
7b
7a
P2
64b
P3
P1
62a
P1
P3
15-2b
14-2a
67d
67b
63
15-1
14-1
61
20

FIG. 12

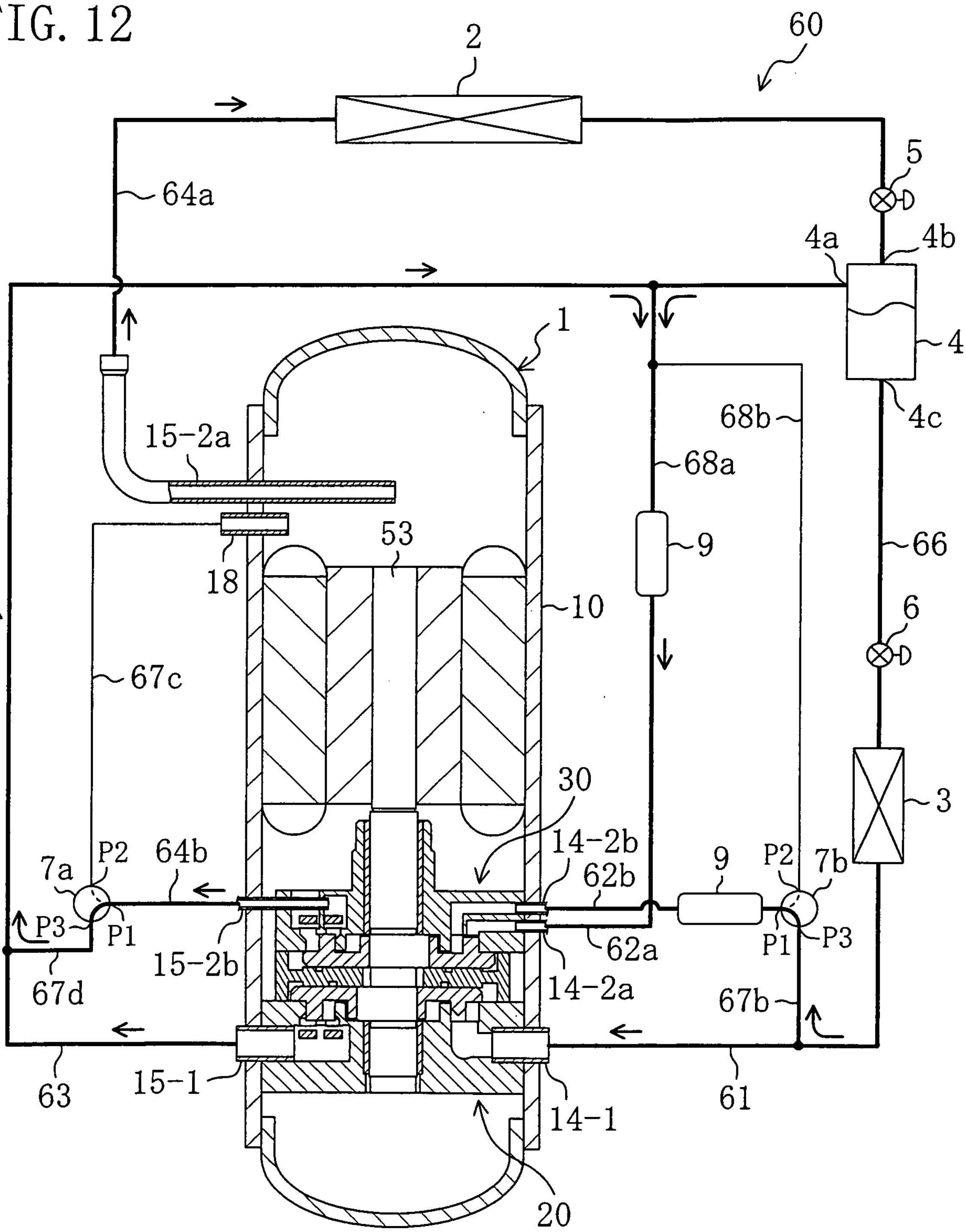

2
60
64a
5
4a
4b
4
1
4c
15-2a
68b
68a
9
66
53
18
10
6
67c
30
3
7a
P2
64b
14-2b
62b
9
P2
7b
P3
P1
15-2b
62a
P1
P3
67d
14-2a
67b
63
15-1
14-1
61
20

FIG. 13

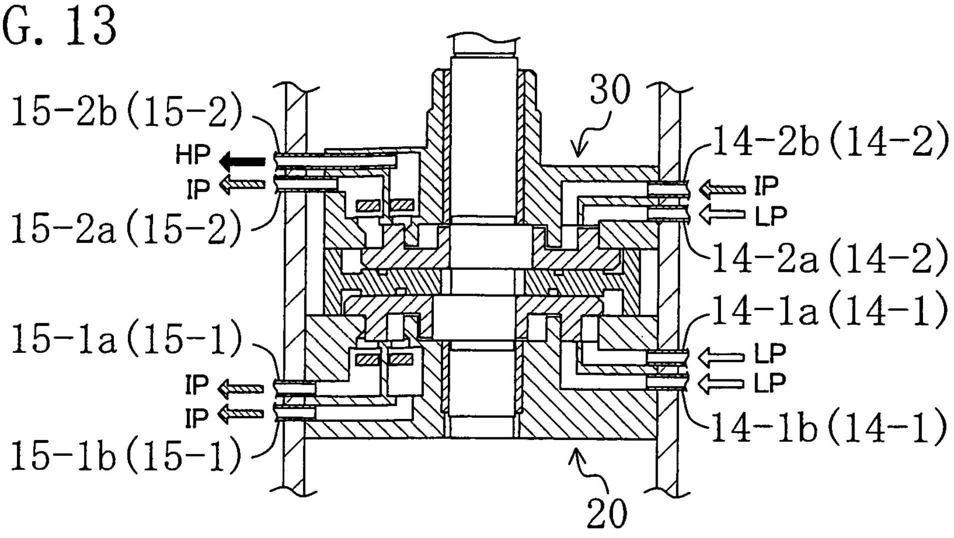


FIG. 14

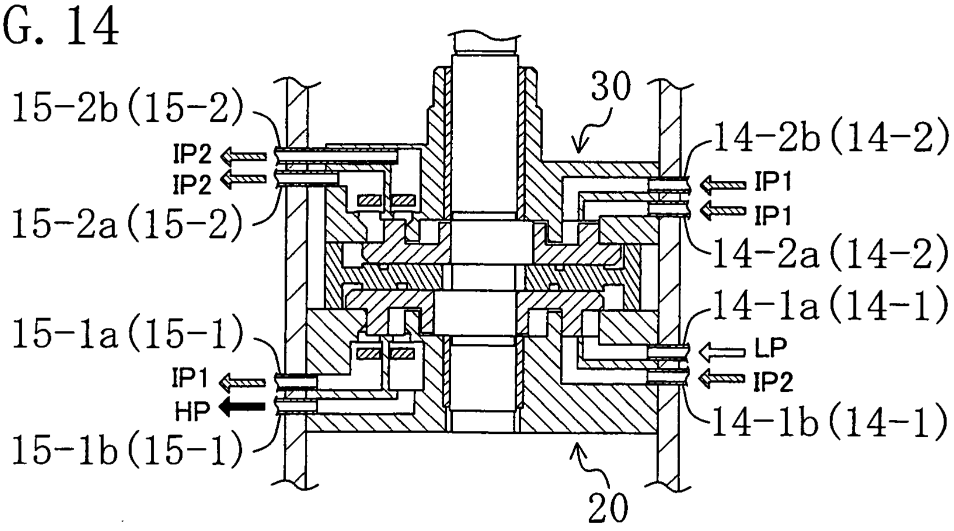


FIG. 15

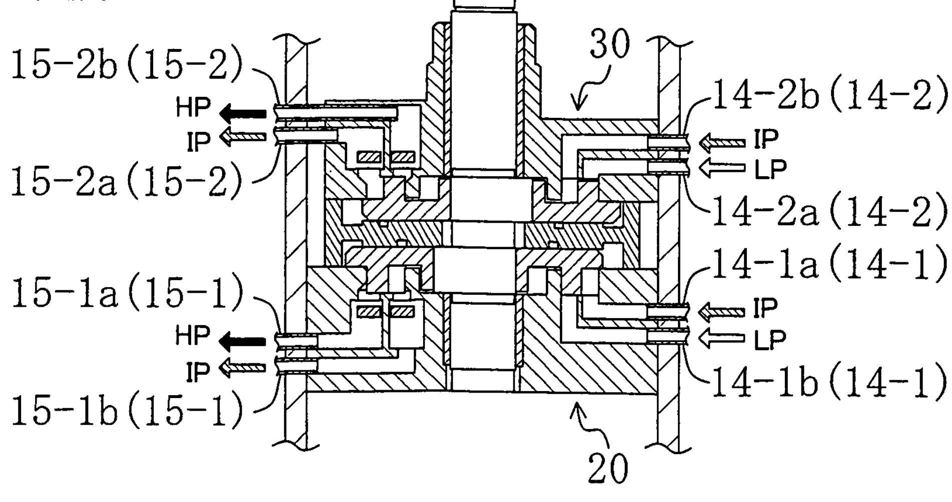


FIG. 16

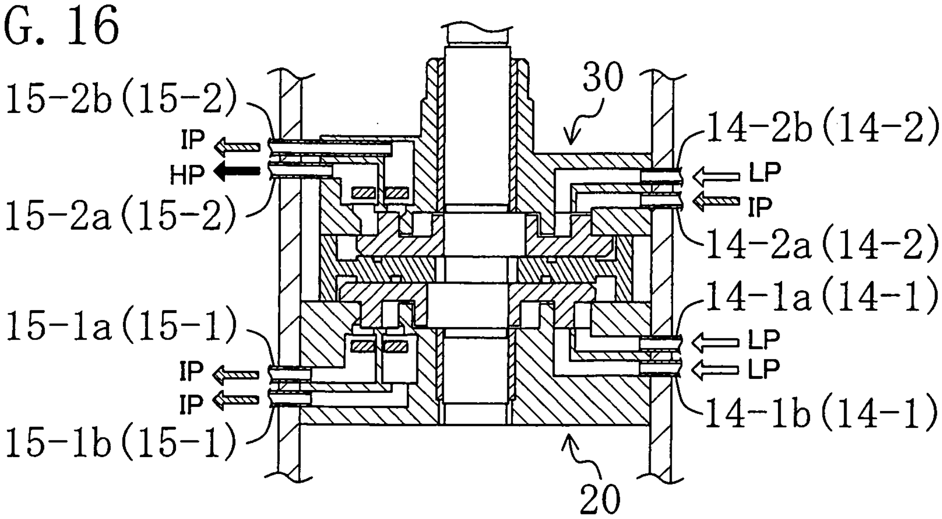


FIG. 17

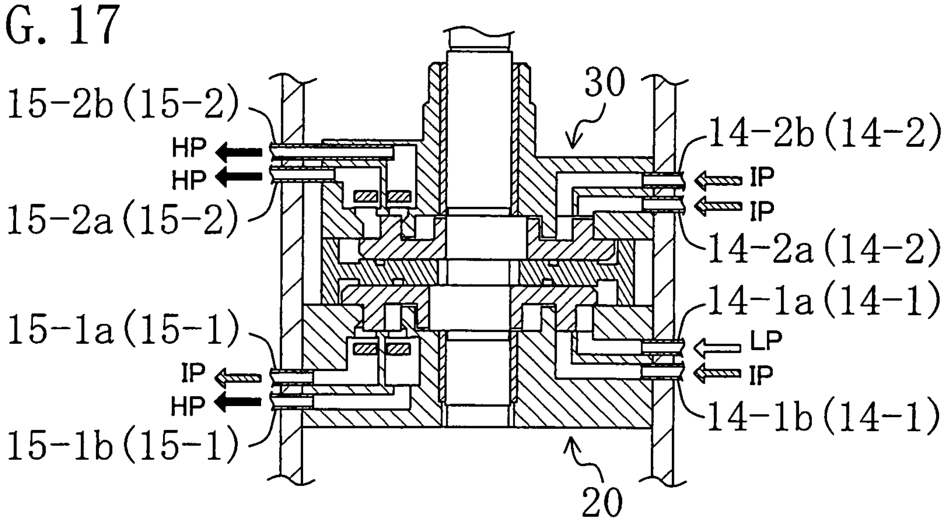


FIG. 18

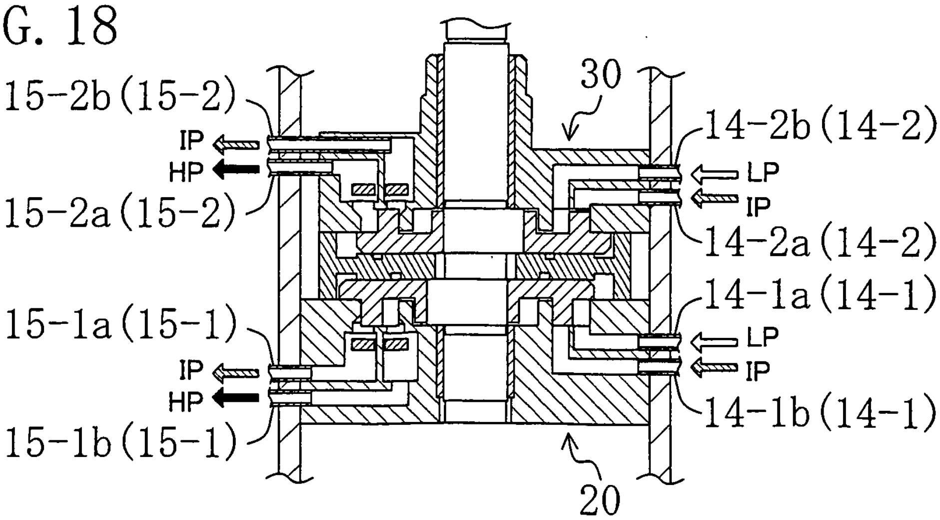


FIG. 19

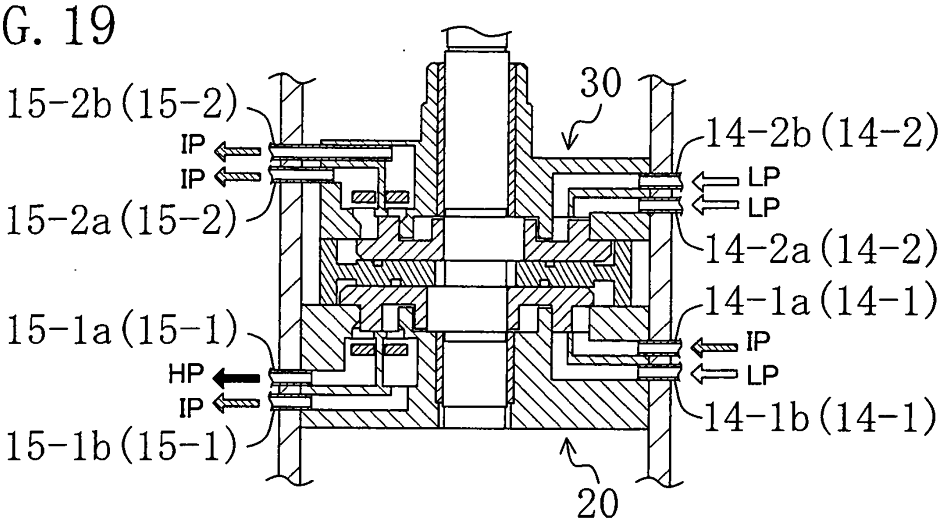


FIG. 20

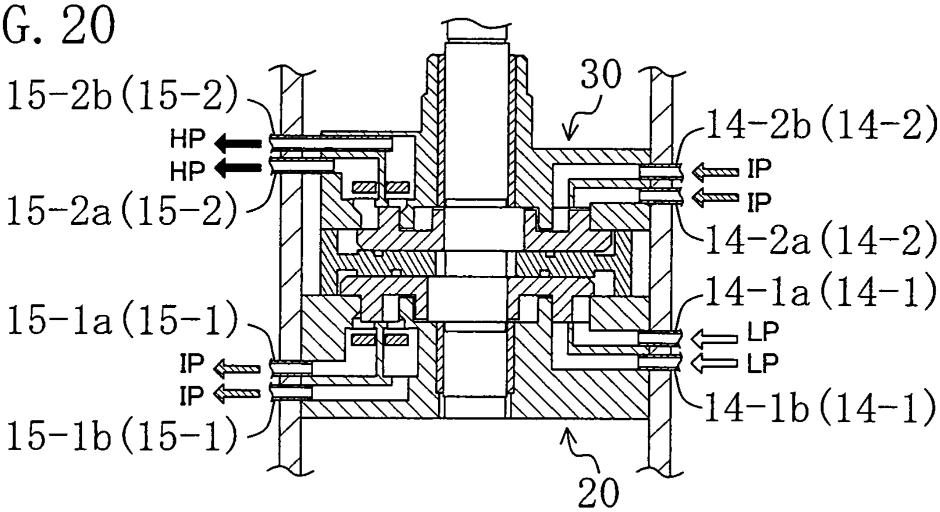


FIG. 21

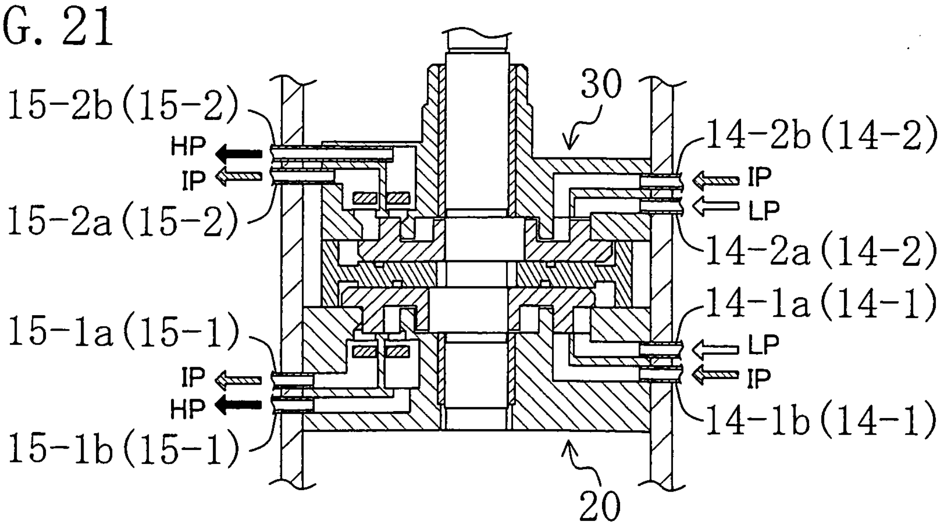
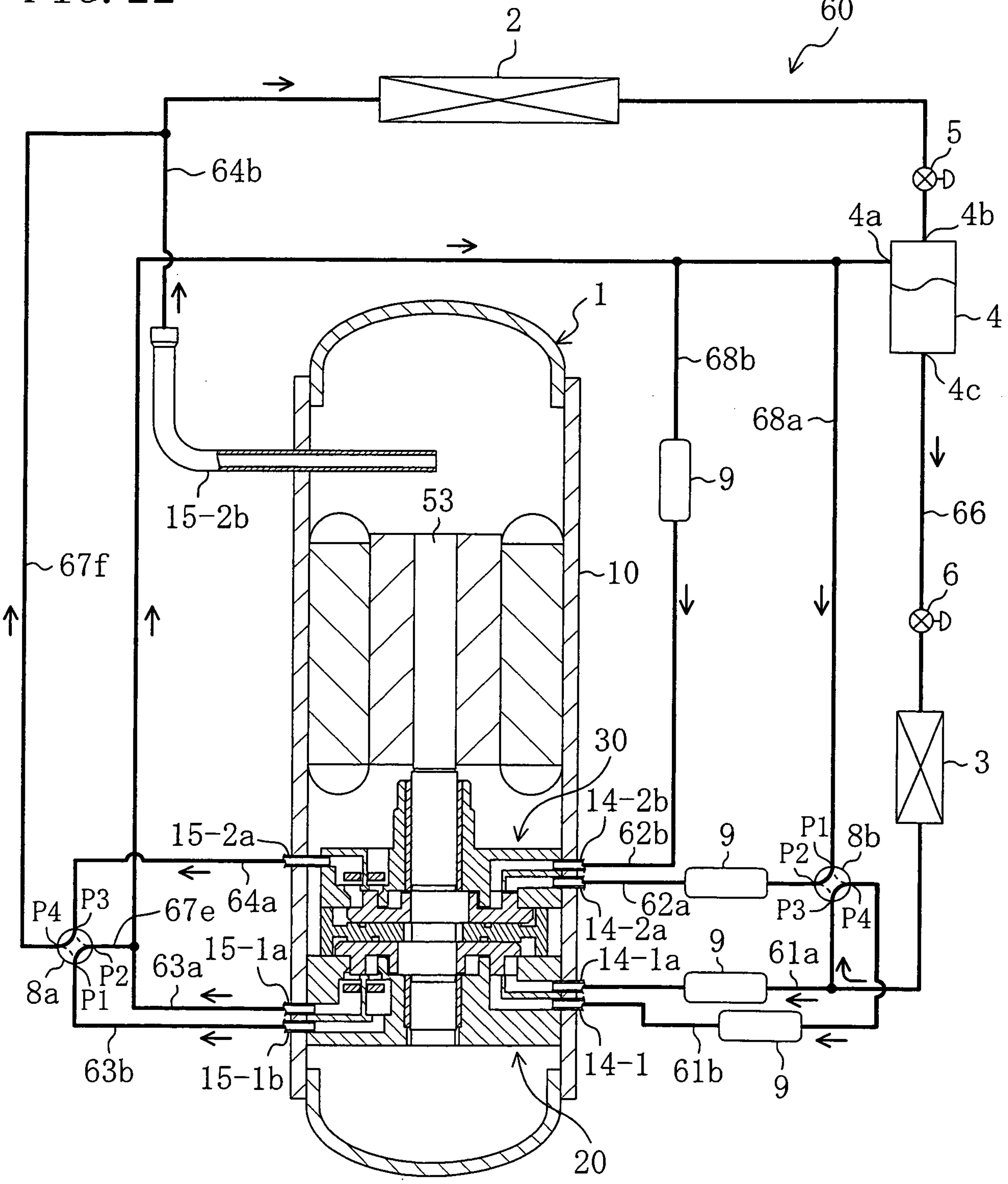


FIG. 22



2
60
5
4a
4b
64b
4
1
4c
68b
68a
15-2b
9
53
66
67f
10
6
3
30
14-2b
15-2a
62b
9
P1
8b
P2
64a
62a
P3
P4
P4
P3
67e
14-2a
15-1a
9
61a
63a
14-1a
P2
8a
P1
63b
15-1b
14-1
61b
9
20

FIG. 23

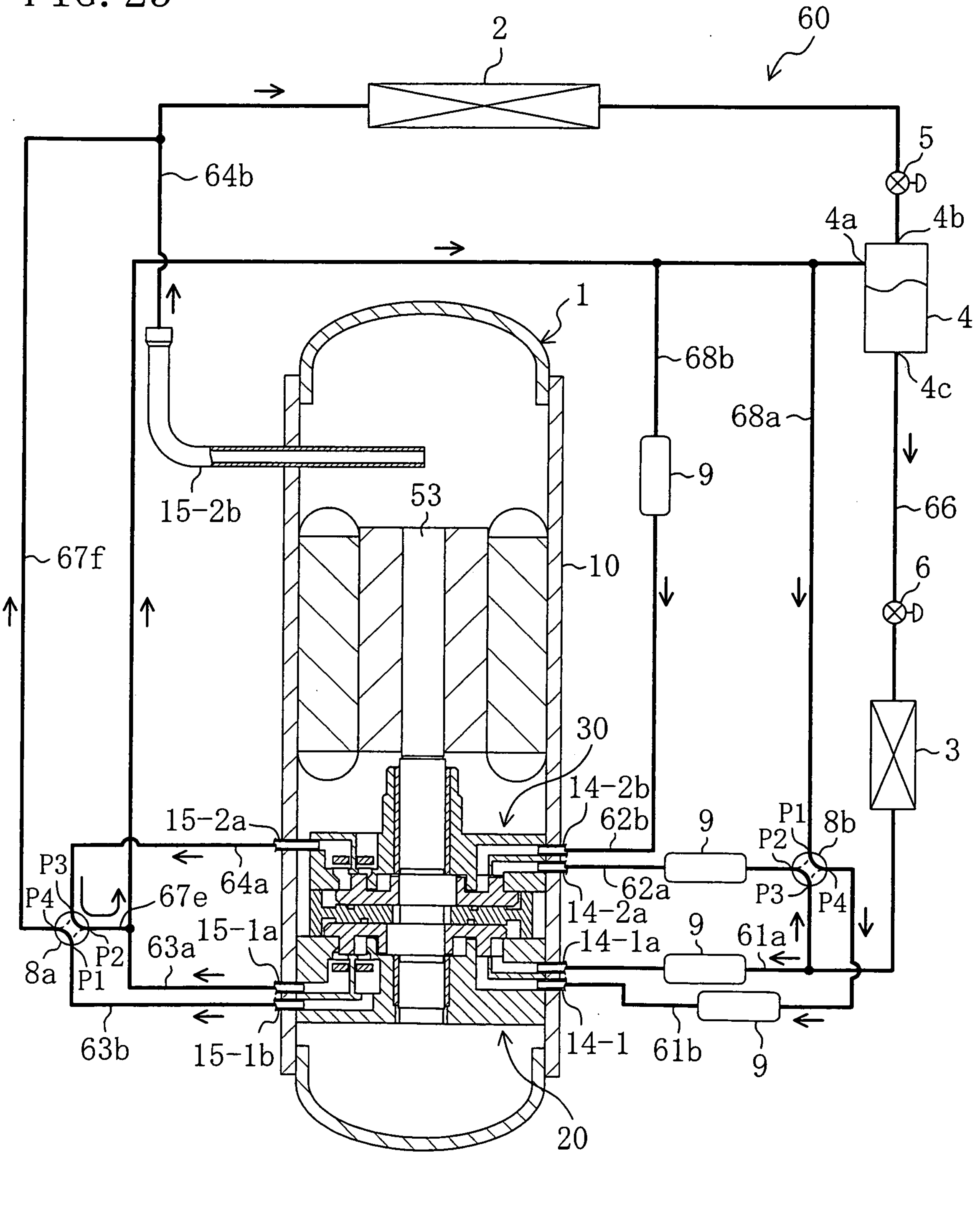
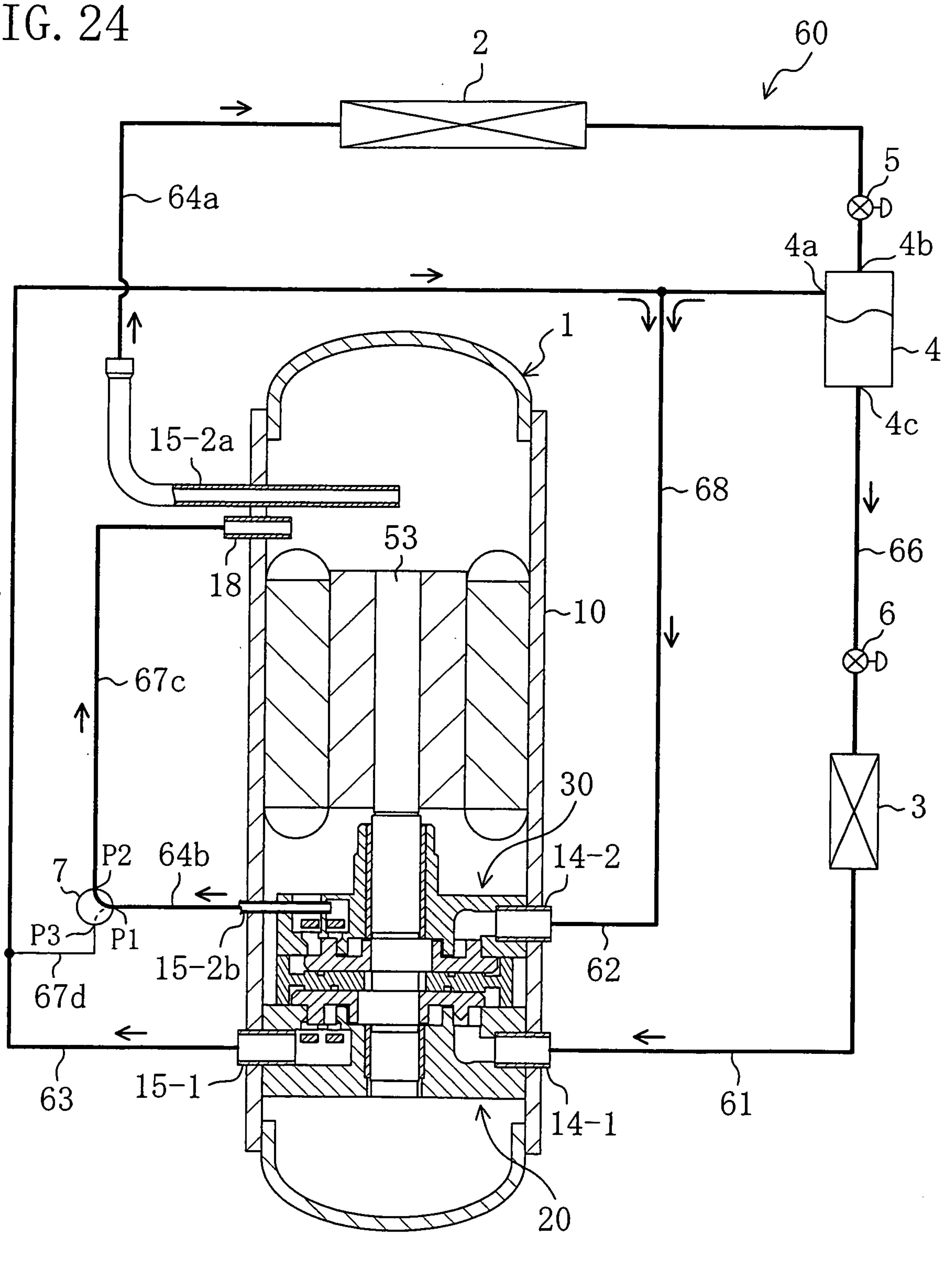
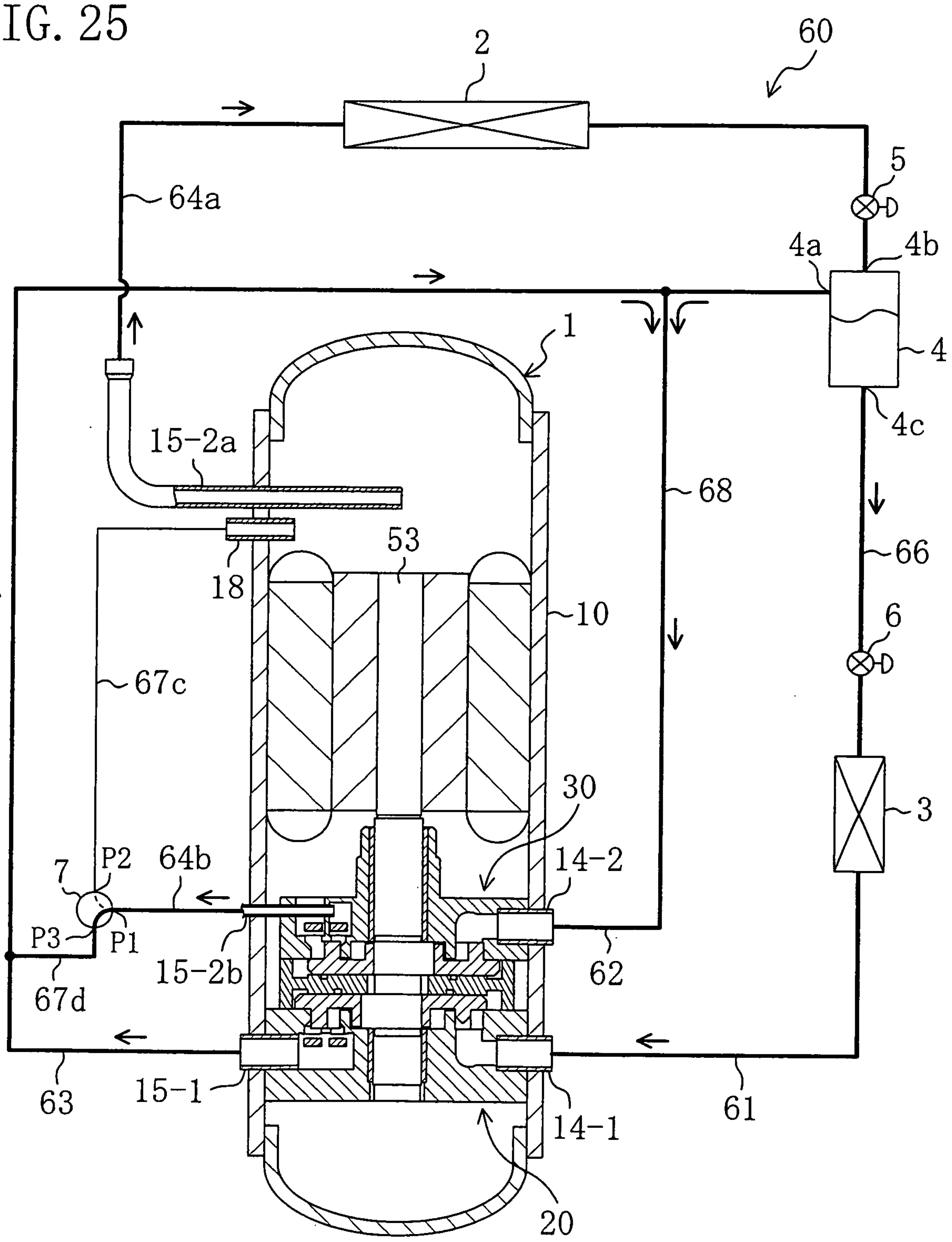

2
60
5
64b
4a
4b
4
1
68b
4c
68a
15-2b
9
53
66
67f
10
6
30
3
14-2b
15-2a
62b
9
P1
8b
P2
P3
64a
62a
P3
P4
67e
14-2a
P4
P1
15-1a
9
P2
14-1a
61a
63a
8a
P1
63b
15-1b
14-1
61b
9
20

FIG. 24



60
2
64a
5
4a
4b
4
1
4c
15-2a
68
53
18
66
10
6
67c
30
3
7
P2
64b
14-2
P3
P1
62
15-2b
67d
63
15-1
14-1
61
20

FIG. 25



60
2
64a
5
4a
4b
4
1
4c
15-2a
68
66
53
18
10
6
67c
30
3
7
P2
64b
14-2
P3
P1
15-2b
62
67d
63
15-1
61
14-1
20

FIG. 26

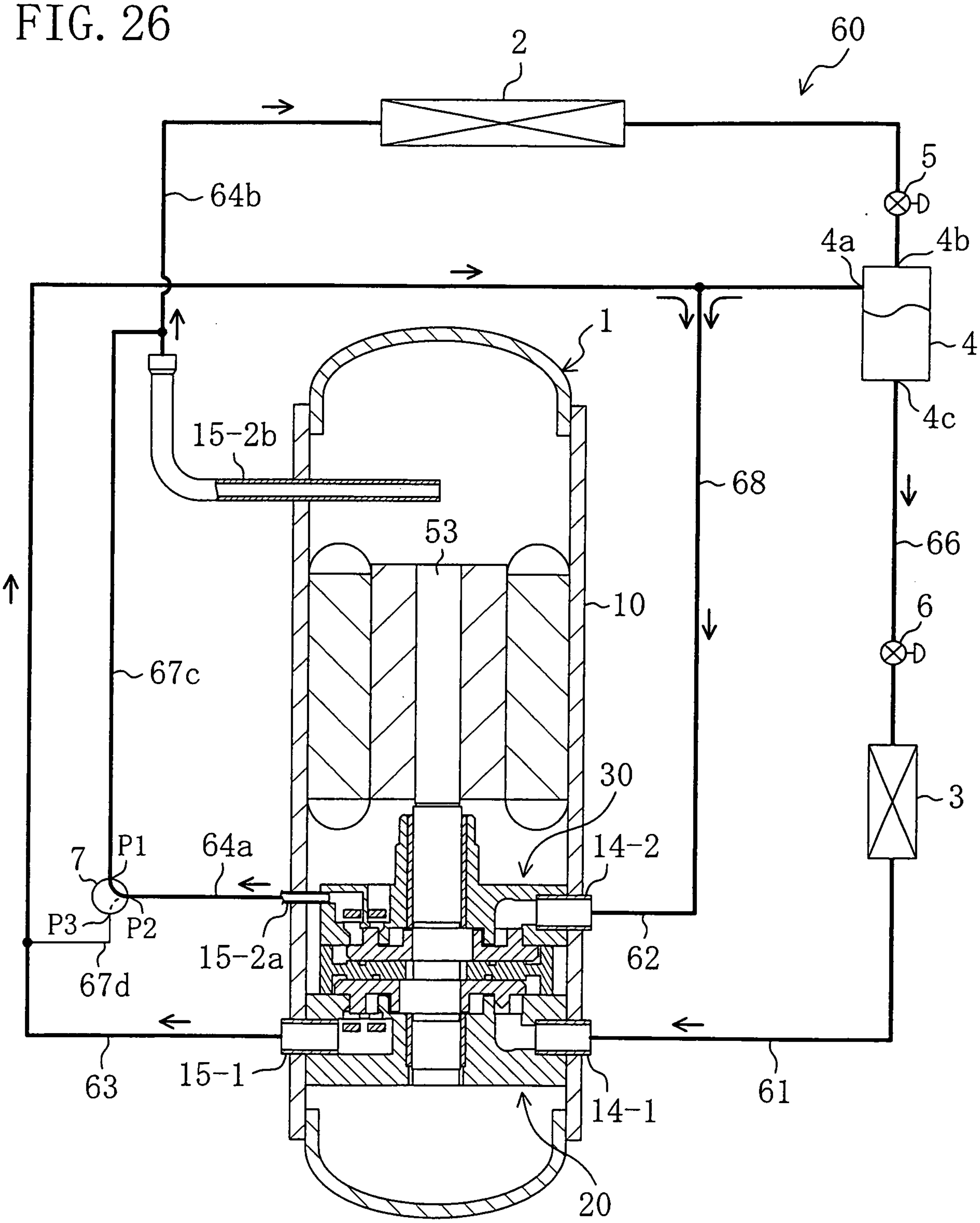
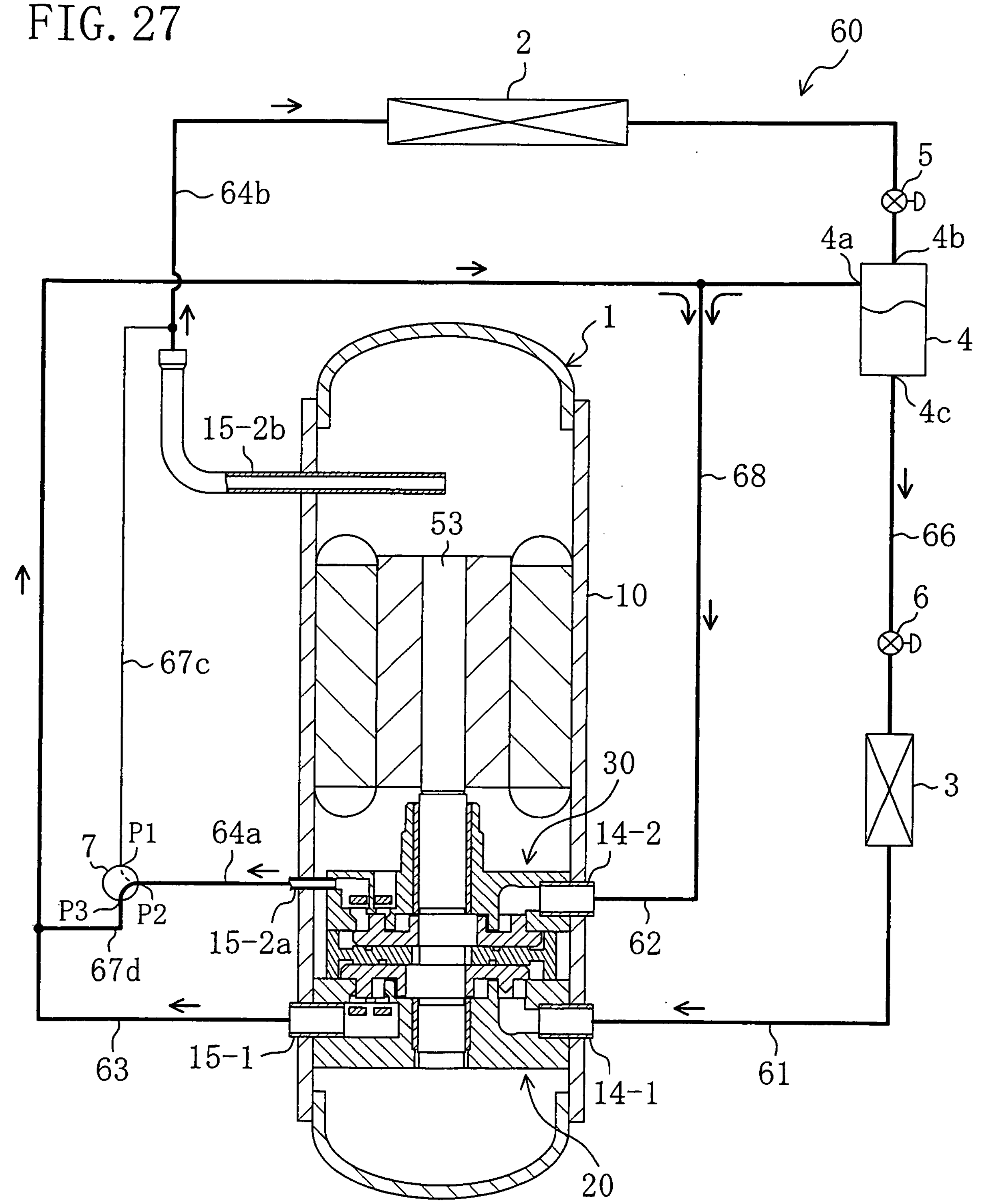
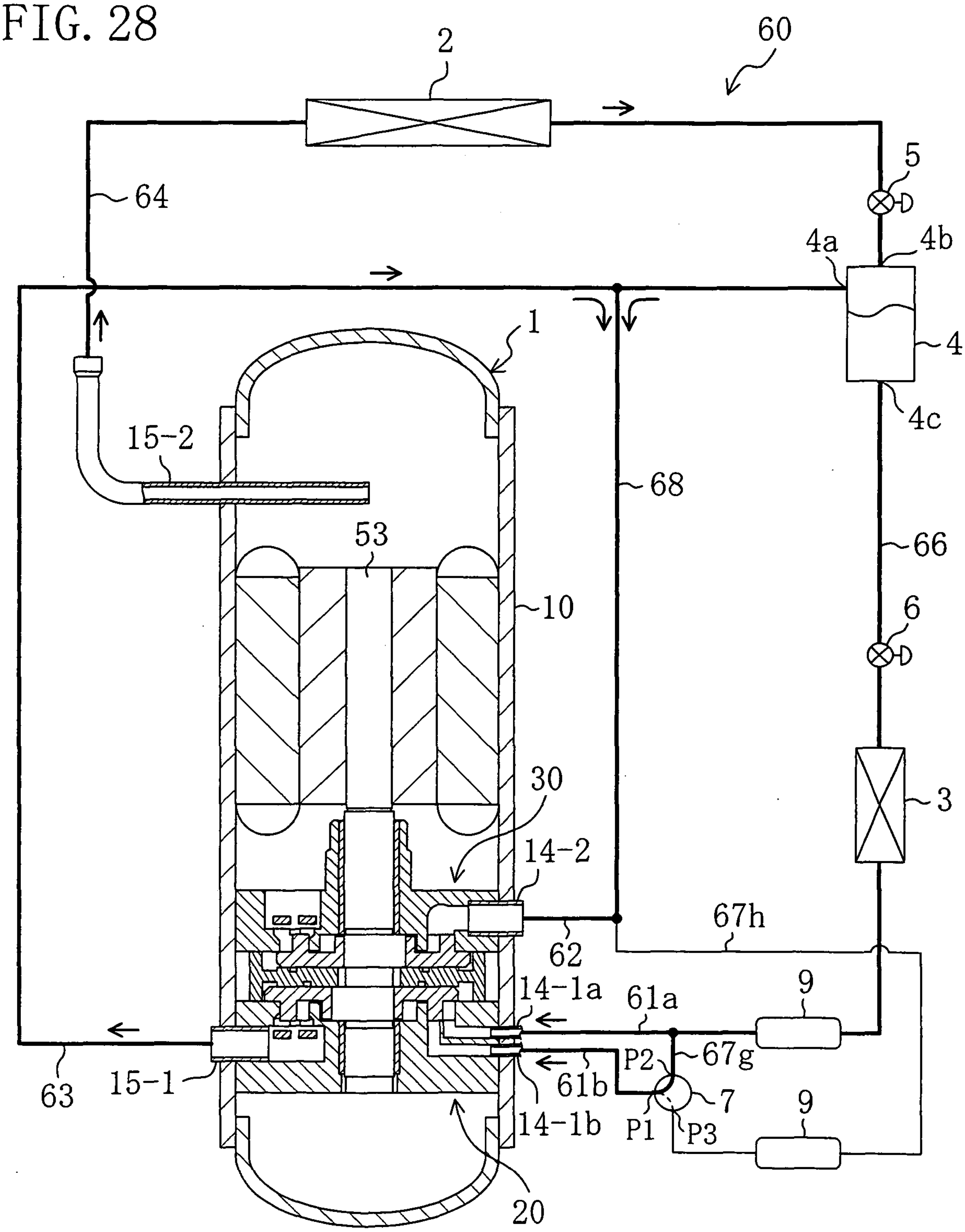

2
60
5
64b
4a
4b
1
4
4c
15-2b
68
53
66
10
6
67c
30
3
7
P1
64a
14-2
P3
P2
62
15-2a
67d
63
15-1
14-1
61
20

FIG. 27



2
60
64b
5
4a
4b
4
1
4c
15-2b
68
53
66
10
6
67c
30
3
7
P1
64a
14-2
P3
P2
15-2a
62
67d
63
15-1
14-1
61
20

FIG. 28



2
60
5
64
4a
4b
4
1
4c
15-2
68
53
66
10
6
30
3
14-2
67h
62
14-1a
9
61a
67g
P2
15-1
61b
7
63
P1
P3
14-1b
9
20

FIG. 29

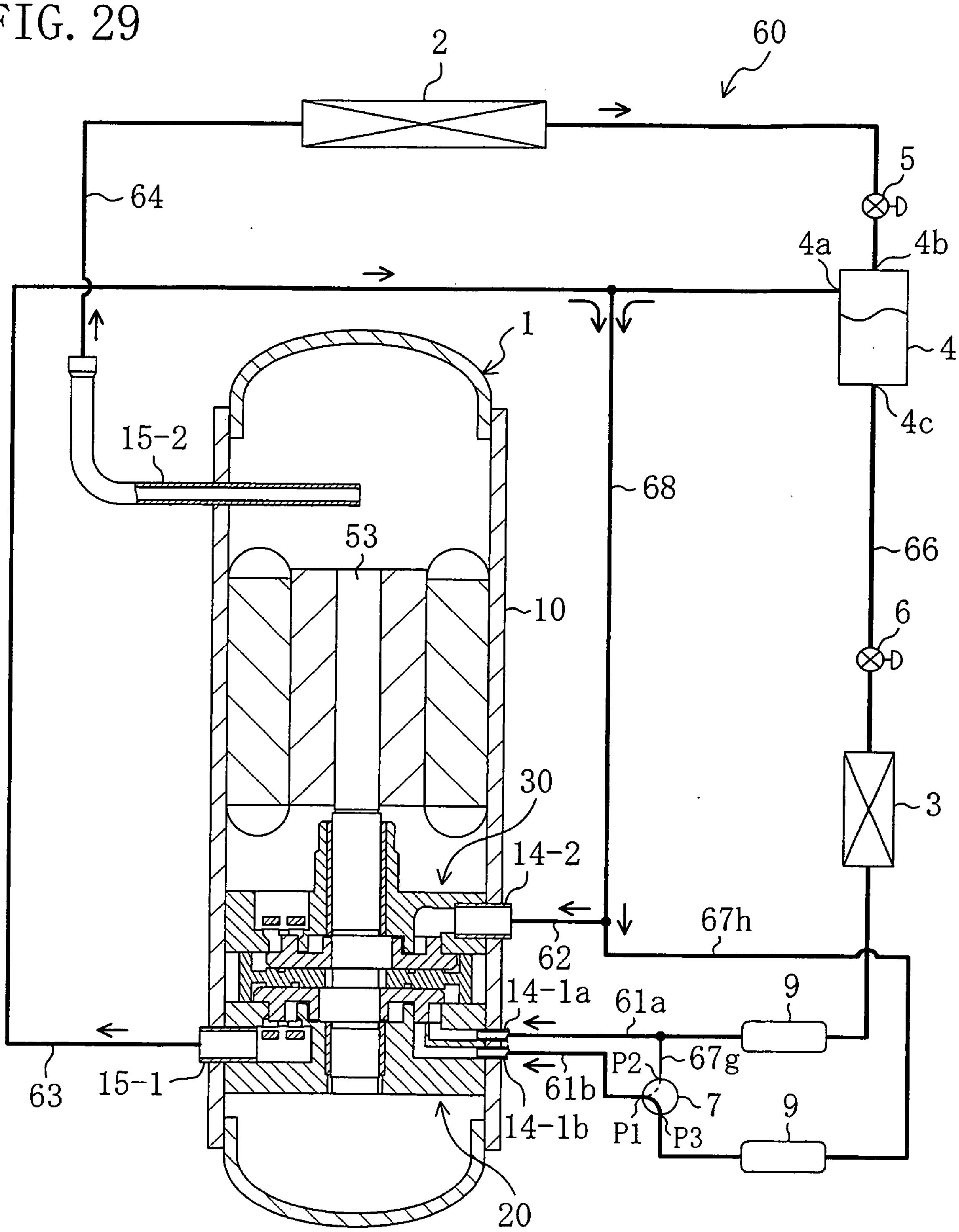
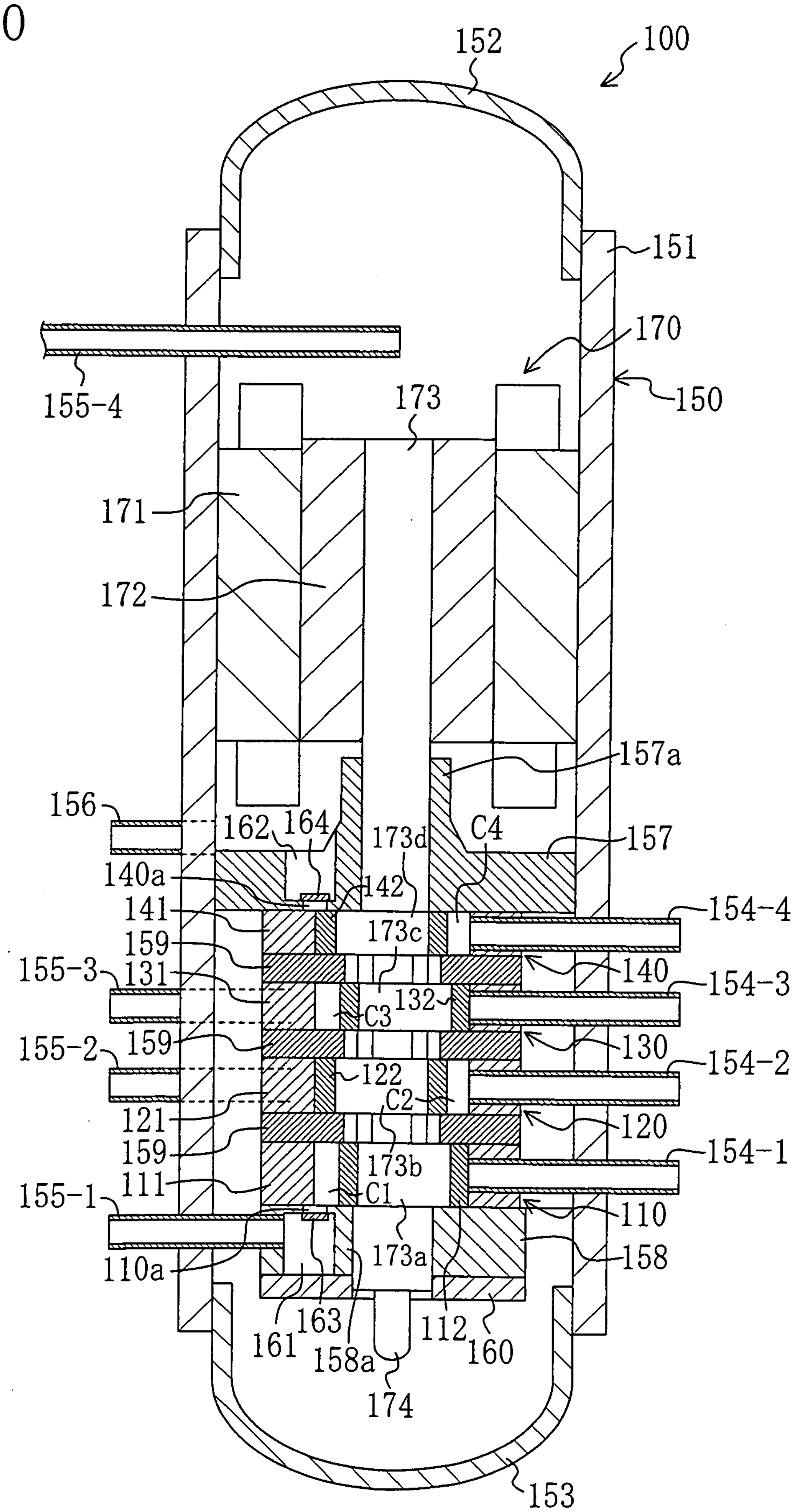

2
60
5
64
4a
4b
4
1
4c
15-2
68
53
66
10
6
30
3
14-2
62
67h
14-1a
61a
9
P2
67g
63
15-1
61b
7
14-1b
P1
P3
9
20

FIG. 30



100
152
151
170
150
155-4
173
171
172
157a
156
162
164
173d
C4
157
140a
142
141
173c
154-4
159
140
155-3
131
132
154-3
C3
155-2
159
130
154-2
122
C2
121
120
159
173b
154-1
111
155-1
C1
110
173a
158
110a
161
163
158a
112
160
174
153

FIG. 31

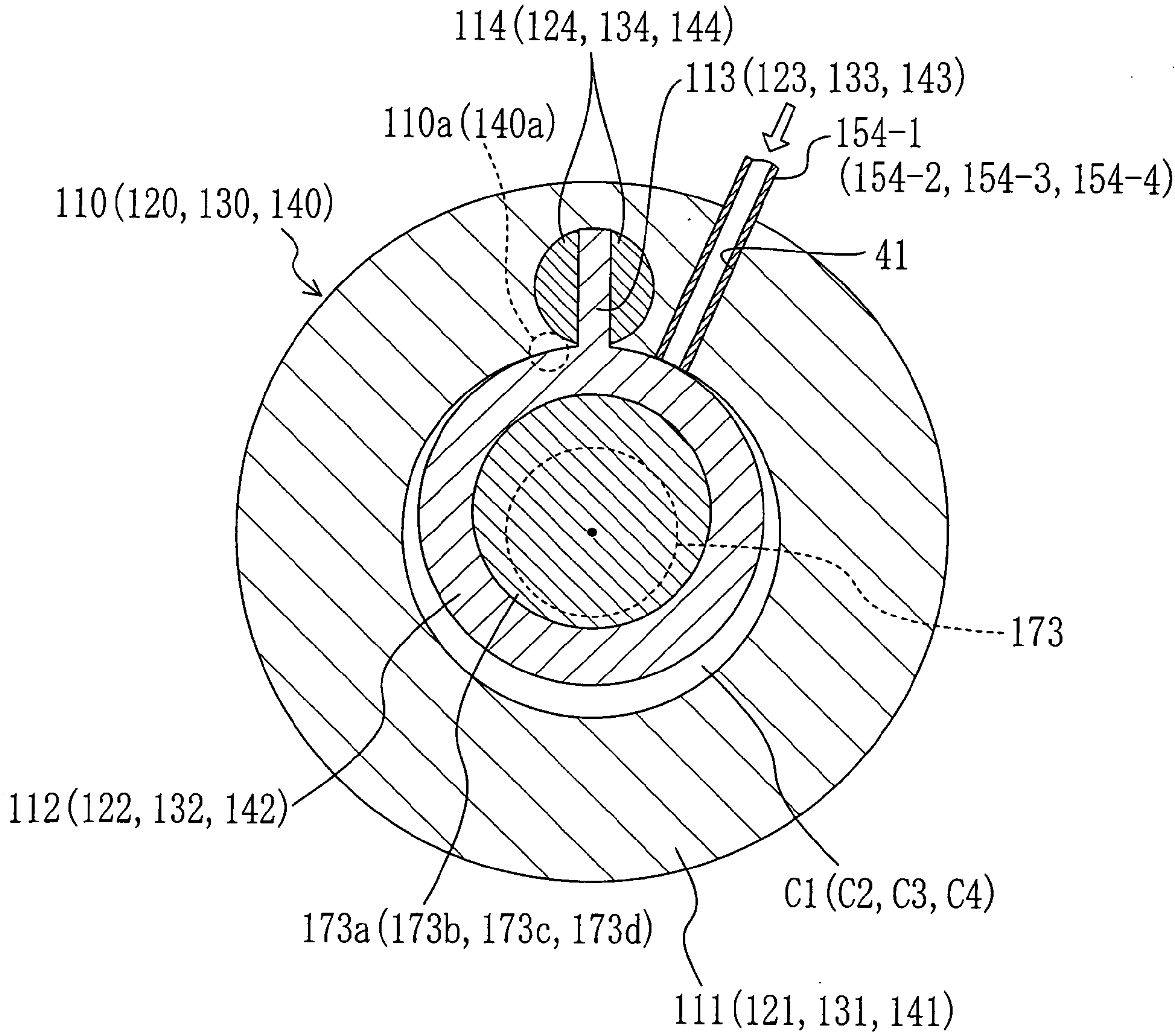

114 (124, 134, 144)
113 (123, 133, 143)
110a (140a)
154-1
(154-2, 154-3, 154-4)
110 (120, 130, 140)
41
173
112 (122, 132, 142)
C1 (C2, C3, C4)
173a (173b, 173c, 173d)
111 (121, 131, 141)

FIG. 32

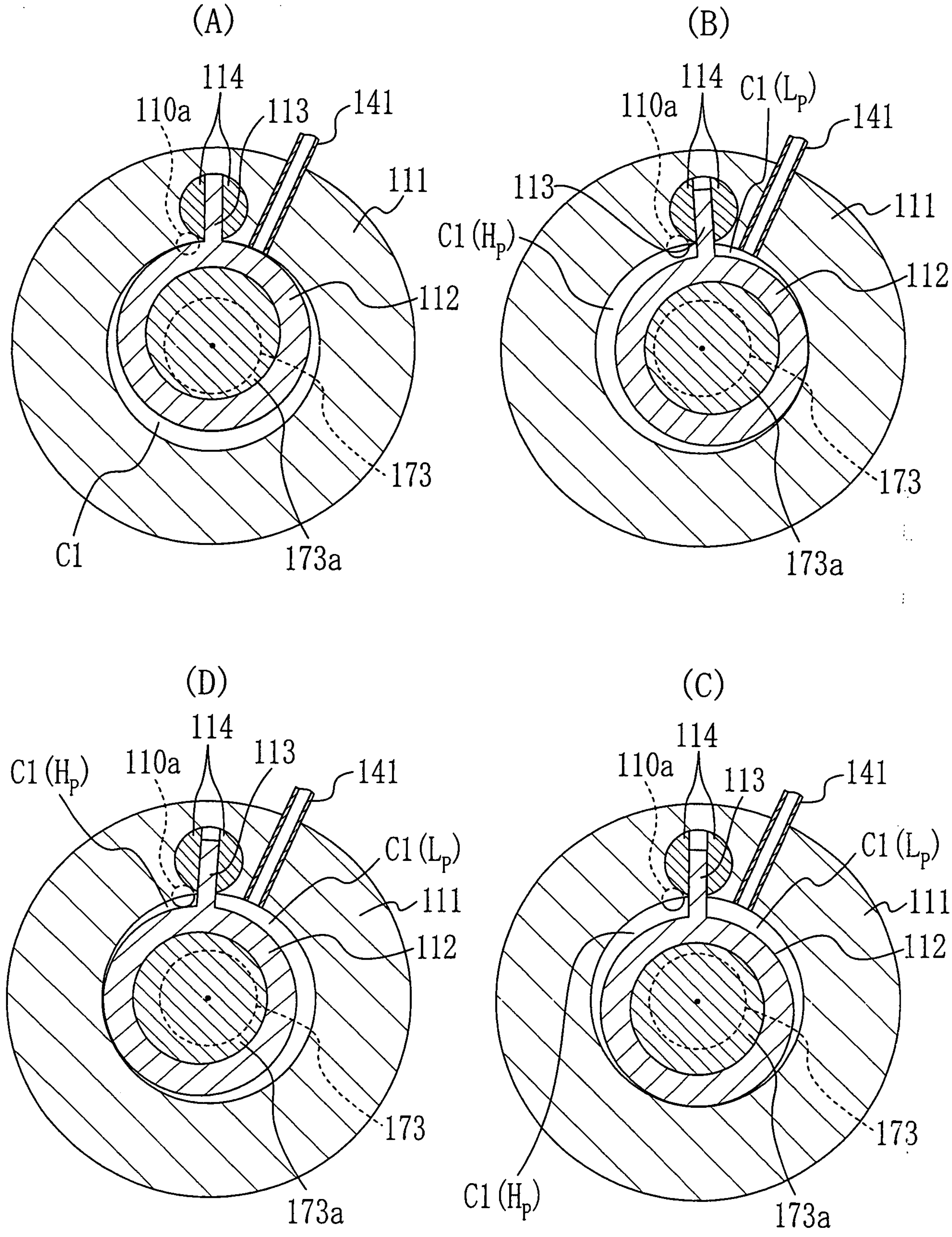
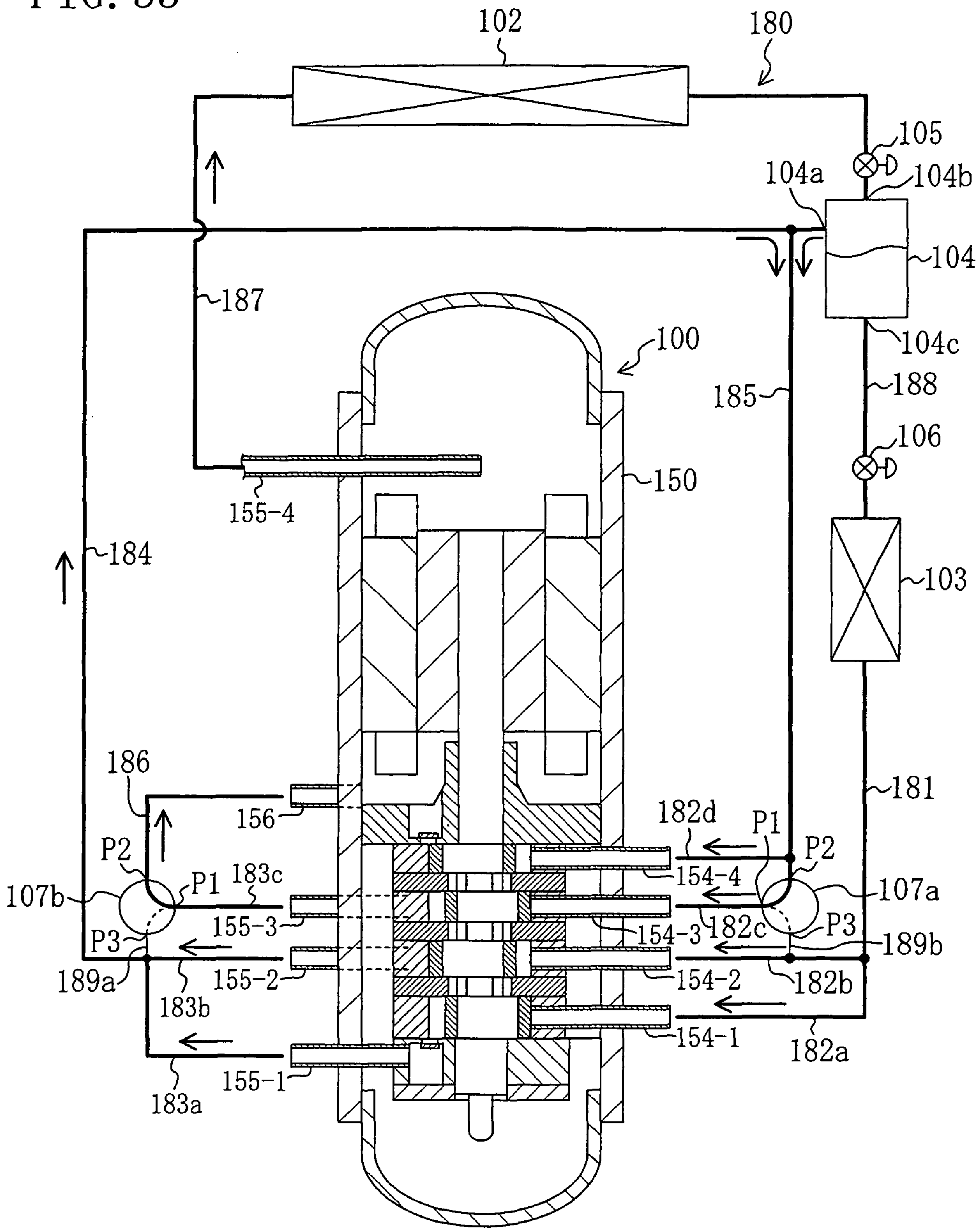

(A)
114
110a
113
141
111
112
173
C1
173a
(B)
114
C1 (Lp)
110a
141
113
111
C1 (Hp)
112
173
173a
(D)
114
C1 (Hp)
110a
113
141
C1 (Lp)
111
112
173
173a
(C)
114
110a
113
141
C1 (Lp)
111
112
173
C1 (Hp)
173a

FIG. 33



102
180
105
104a
104b
104
187
100
104c
185
188
106
150
155-4
184
103
186
181
156
182d
P1
P2
P2
P1
183c
107b
107a
154-4
155-3
154-3
182c
P3
P3
189b
155-2
154-2
189a
183b
182b
154-1
182a
155-1
183a

FIG. 34

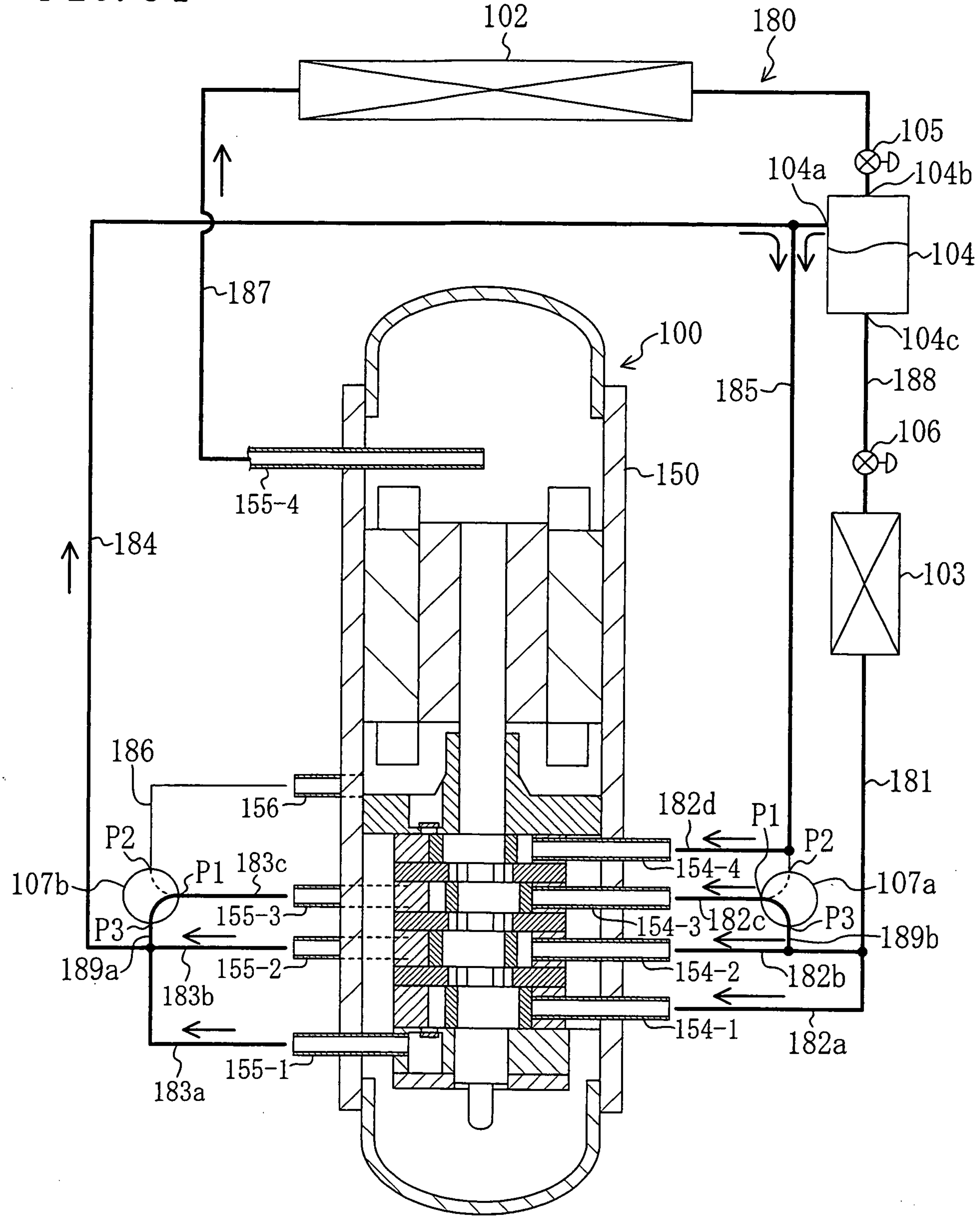
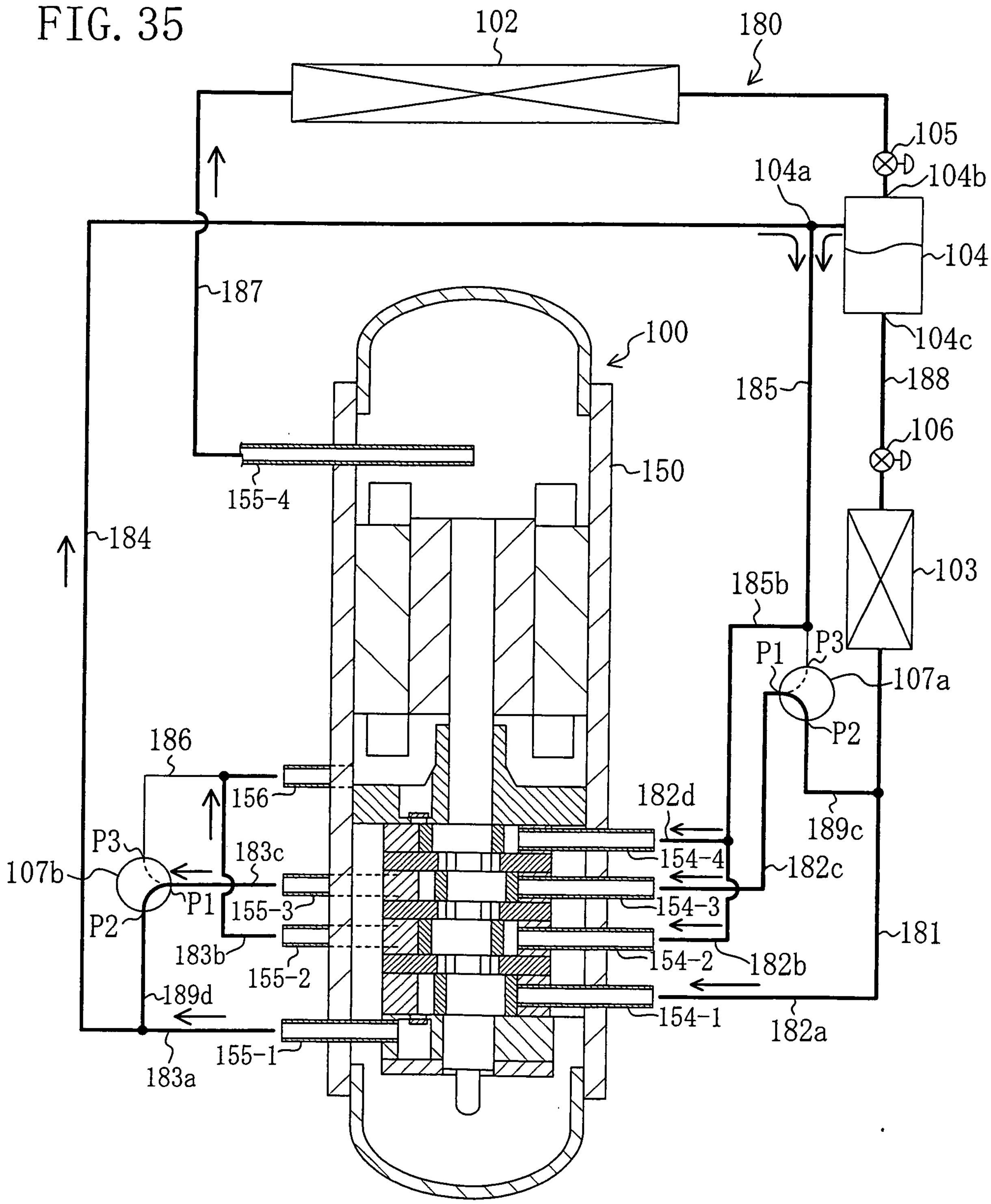

102
180
105
104a
104b
104
187
100
104c
185
188
106
155-4
150
184
103
186
181
156
182d
P1
P2
P2
154-4
107b
P1
183c
107a
155-3
154-3
182c
P3
P3
189b
189a
155-2
154-2
182b
183b
154-1
182a
155-1
183a

FIG. 35



102
180
105
104a
104b
104
187
100
104c
185
188
106
150
155-4
184
103
185b
P1
P3
107a
P2
186
156
182d
189c
P3
183c
154-4
182c
107b
P1
155-3
154-3
P2
181
183b
155-2
154-2
182b
189d
154-1
155-1
182a
183a

FIG. 36

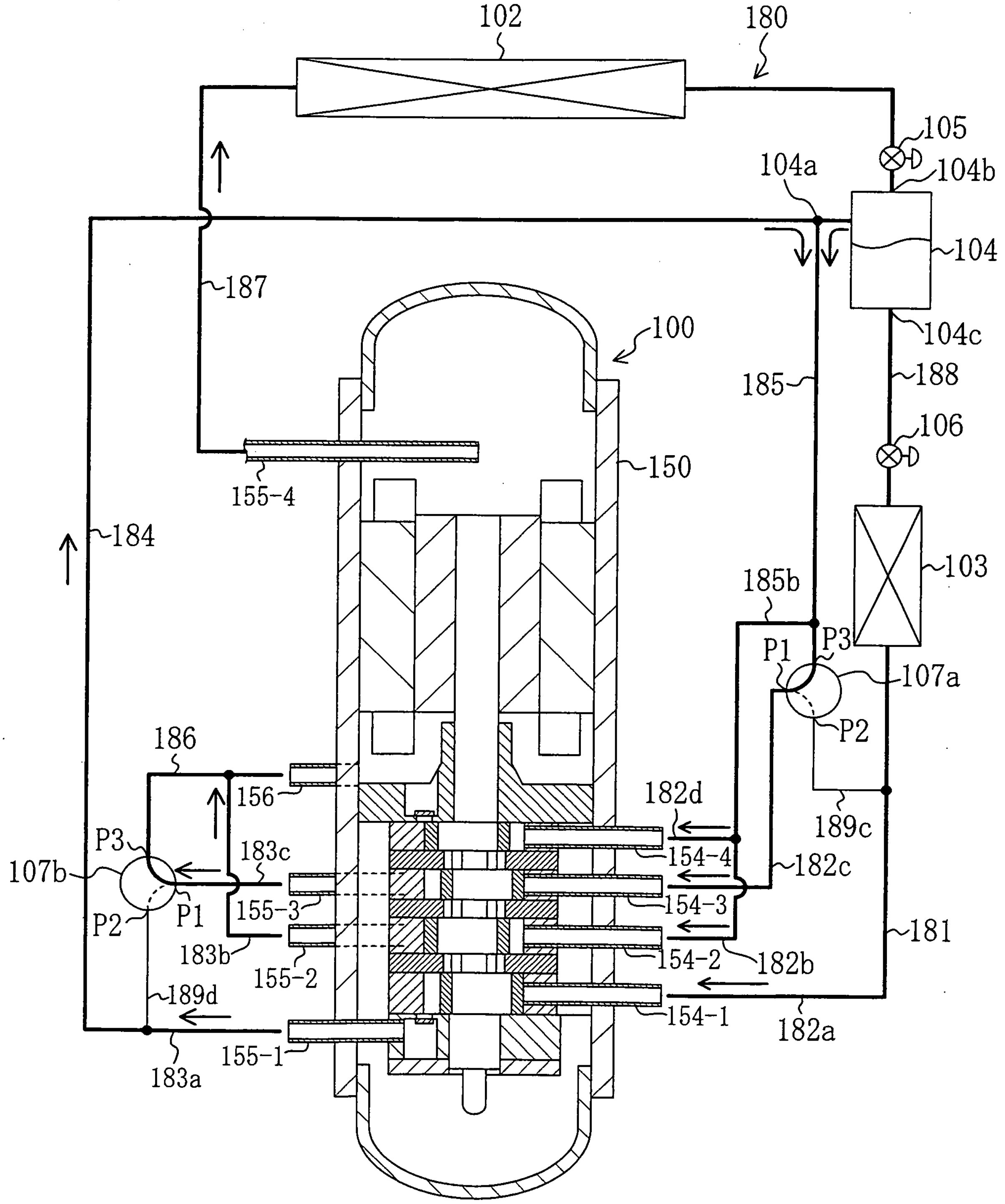
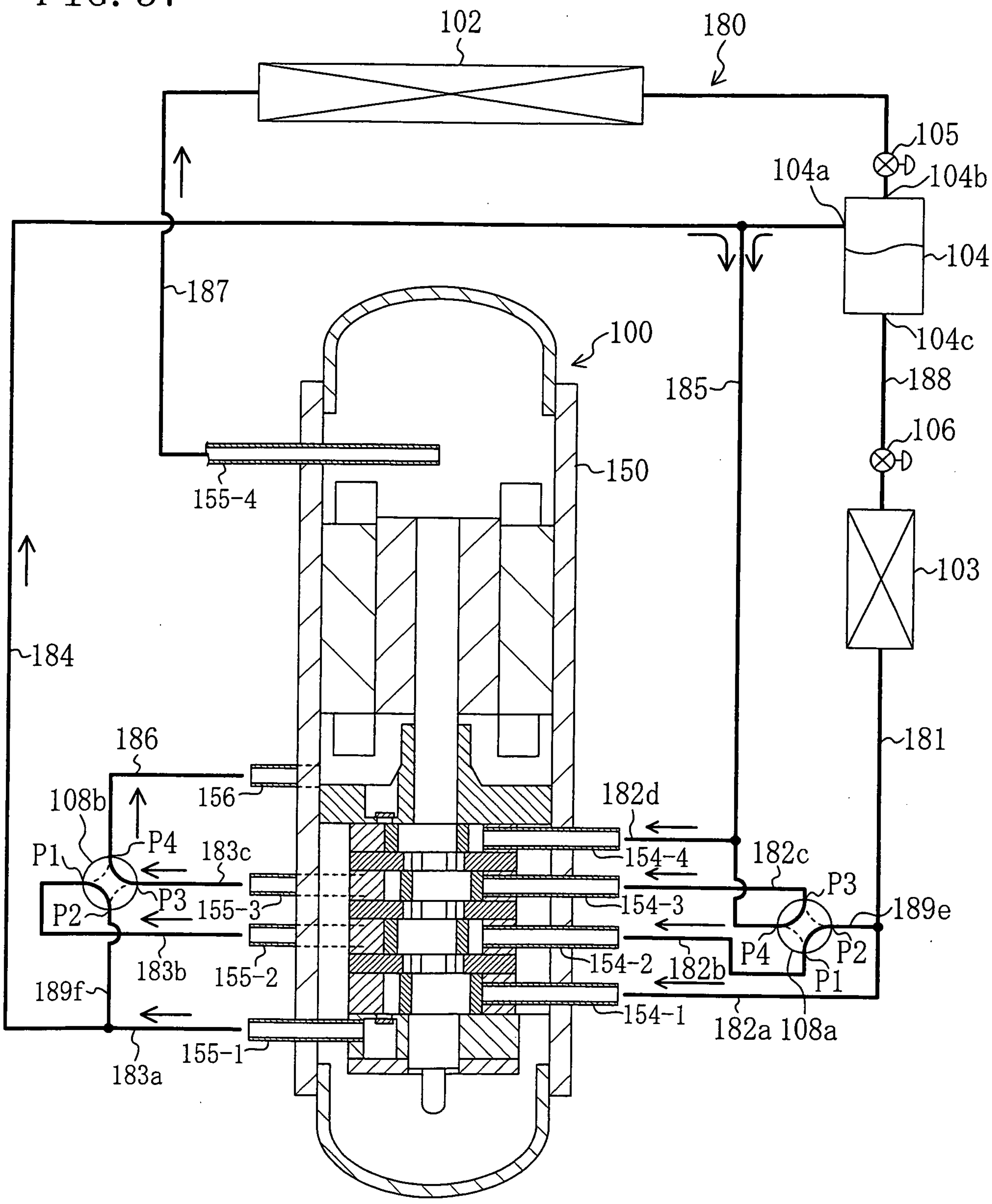

102
180
105
104a
104b
104
187
100
104c
185
188
106
150
155-4
184
103
185b
P1
P3
107a
P2
186
156
182d
189c
P3
183c
154-4
182c
107b
155-3
154-3
P2
P1
181
183b
155-2
154-2
182b
189d
154-1
182a
155-1
183a

FIG. 37



102
180
105
104a
104b
104
187
100
104c
185
188
106
150
155-4
103
184
186
181
156
182d
108b
P1
P4
183c
154-4
182c
P3
P3
155-3
154-3
189e
P2
P4
P2
183b
155-2
154-2
182b
P1
189f
154-1
182a
108a
155-1
183a

FIG. 38

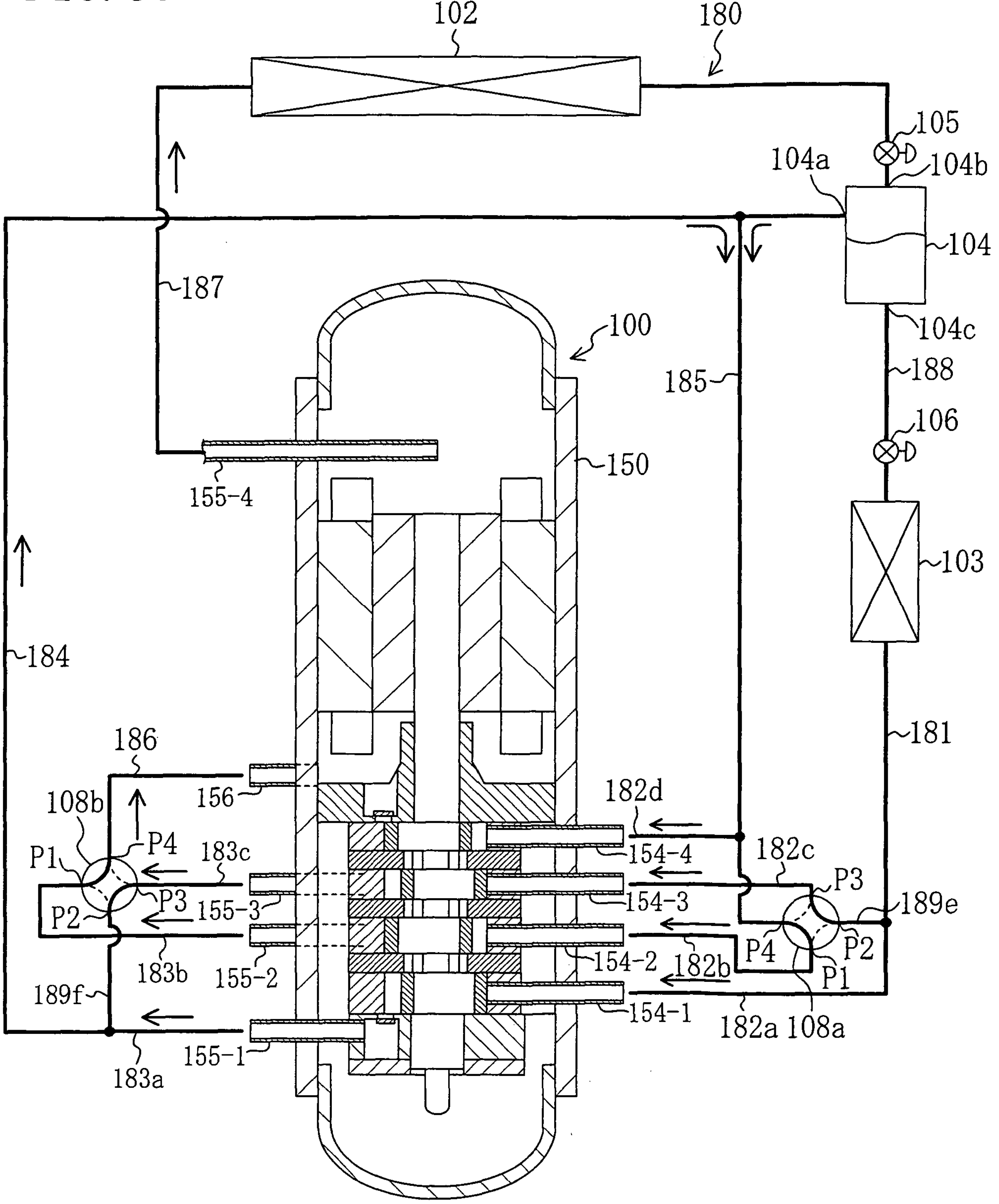

102
180
105
104a
104b
104
104c
187
100
185
188
106
150
155-4
103
184
181
186
156
182d
108b
P4
154-4
182c
P1
183c
P3
P3
154-3
189e
P2
155-3
P4
P2
154-2
182b
183b
155-2
P1
189f
154-1
182a
108a
155-1
183a

FIG. 39

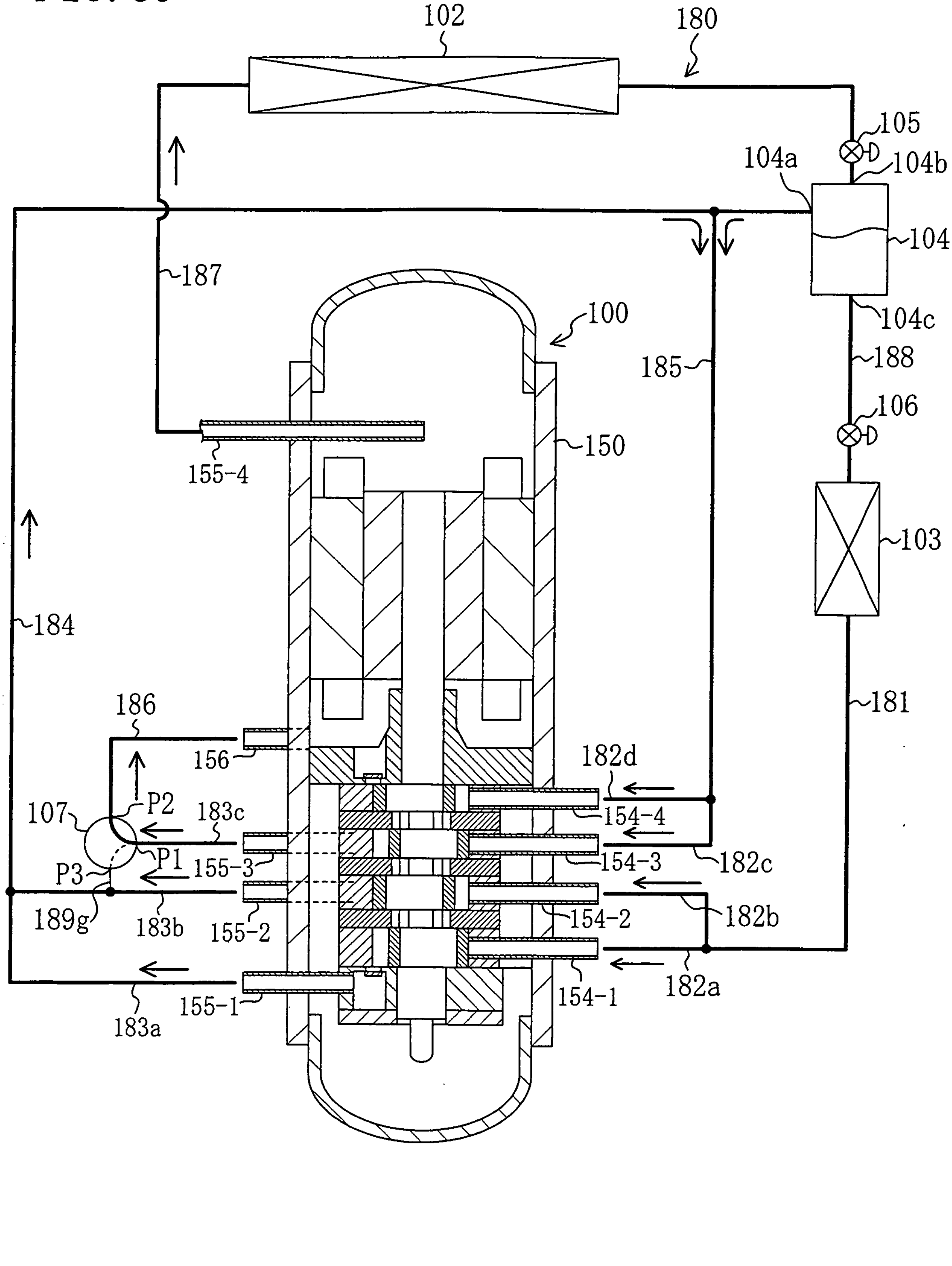
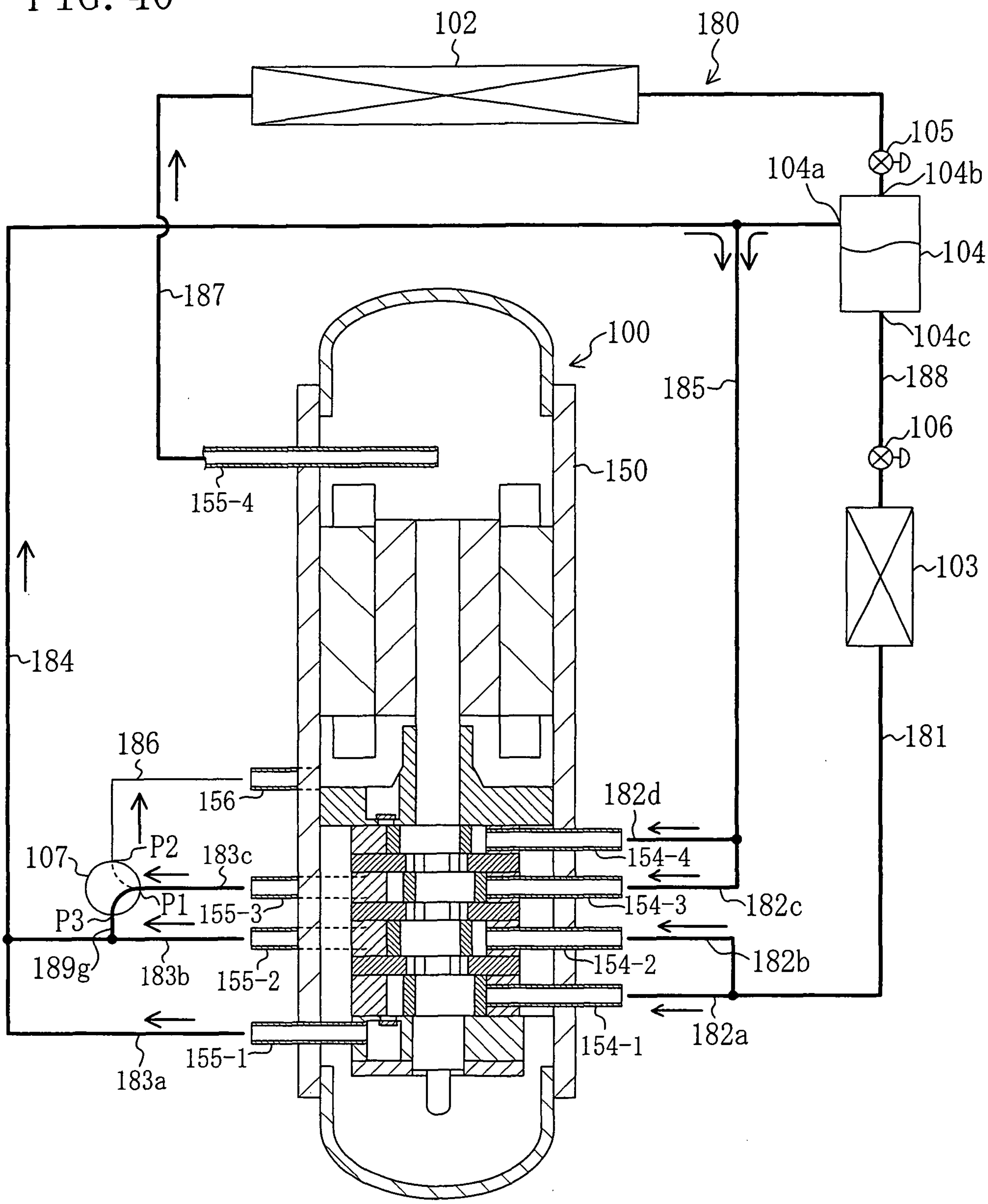
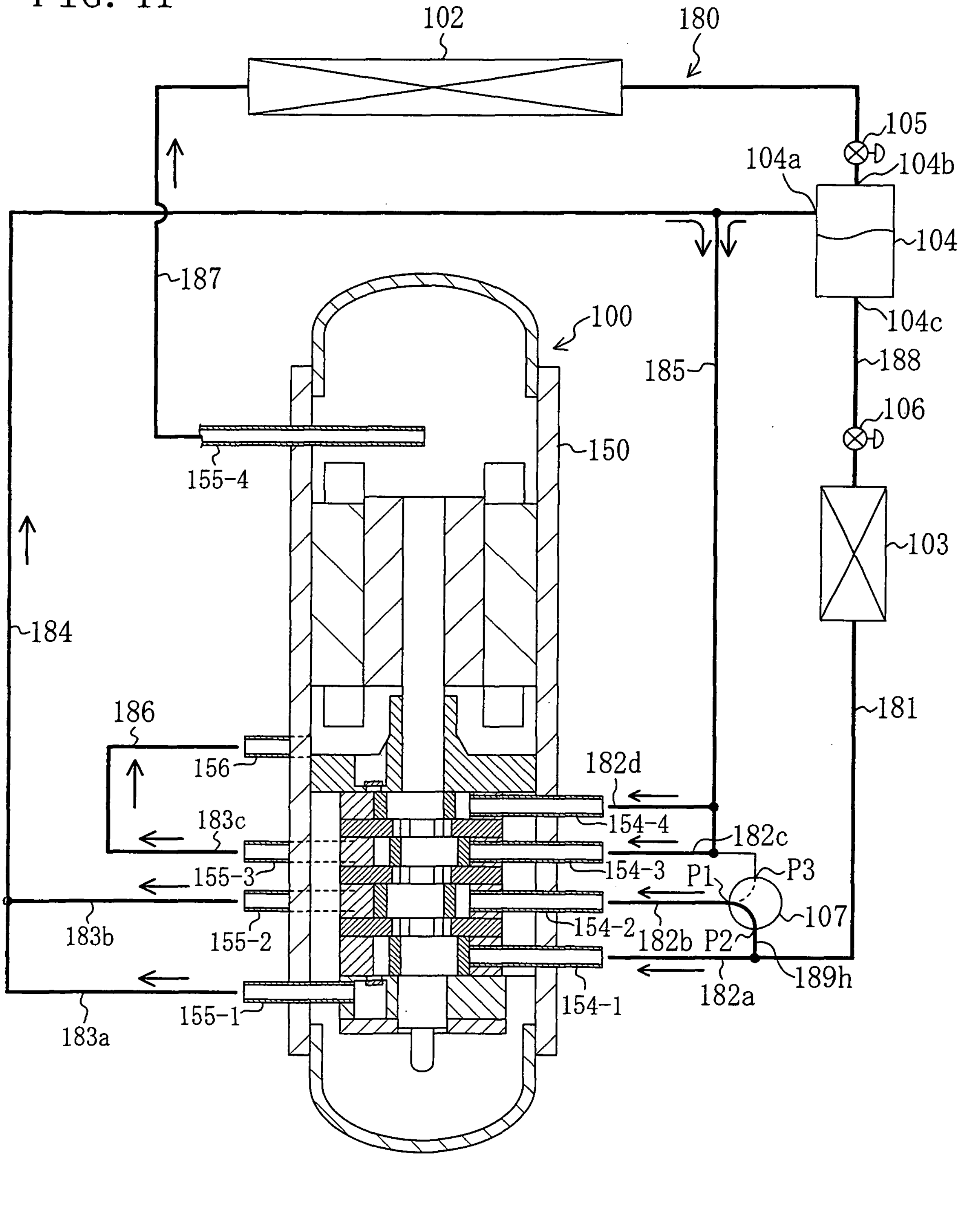

102
180
105
104a
104b
104
104c
188
106
103
181
187
100
185
150
155-4
184
186
156
182d
154-4
107
P2
183c
P1
182c
155-3
154-3
P3
155-2
154-2
182b
189g
183b
155-1
154-1
182a
183a

FIG. 40



102
180
105
104a
104b
104
187
100
185
104c
188
106
150
155-4
103
184
181
186
182d
156
107
P2
183c
154-4
P1
154-3
182c
P3
155-3
189g
183b
155-2
154-2
182b
155-1
154-1
182a
183a

FIG. 41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180
105
104a
104b
104
187
100
104c
185
188
106
150
155-4
103
184
181
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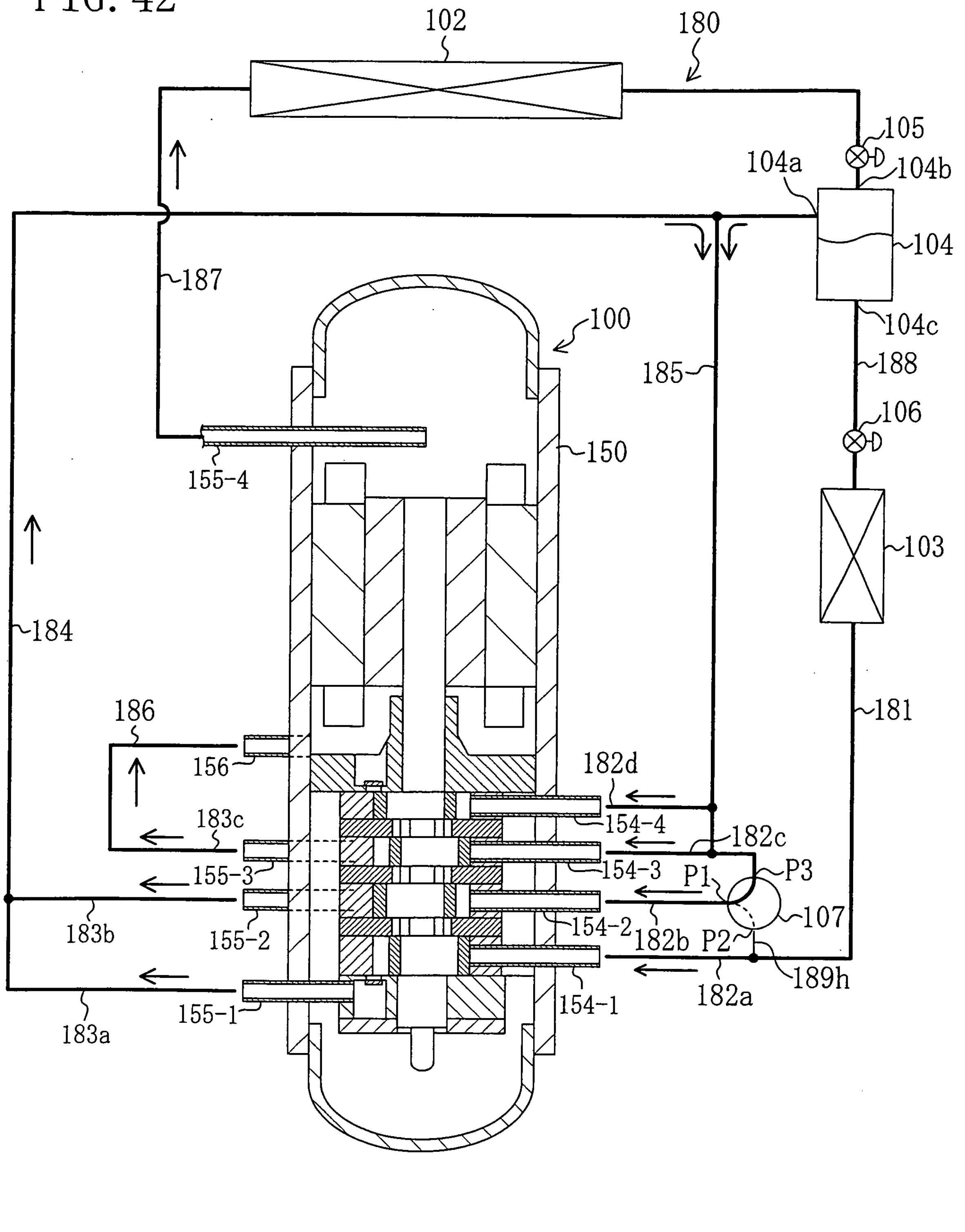
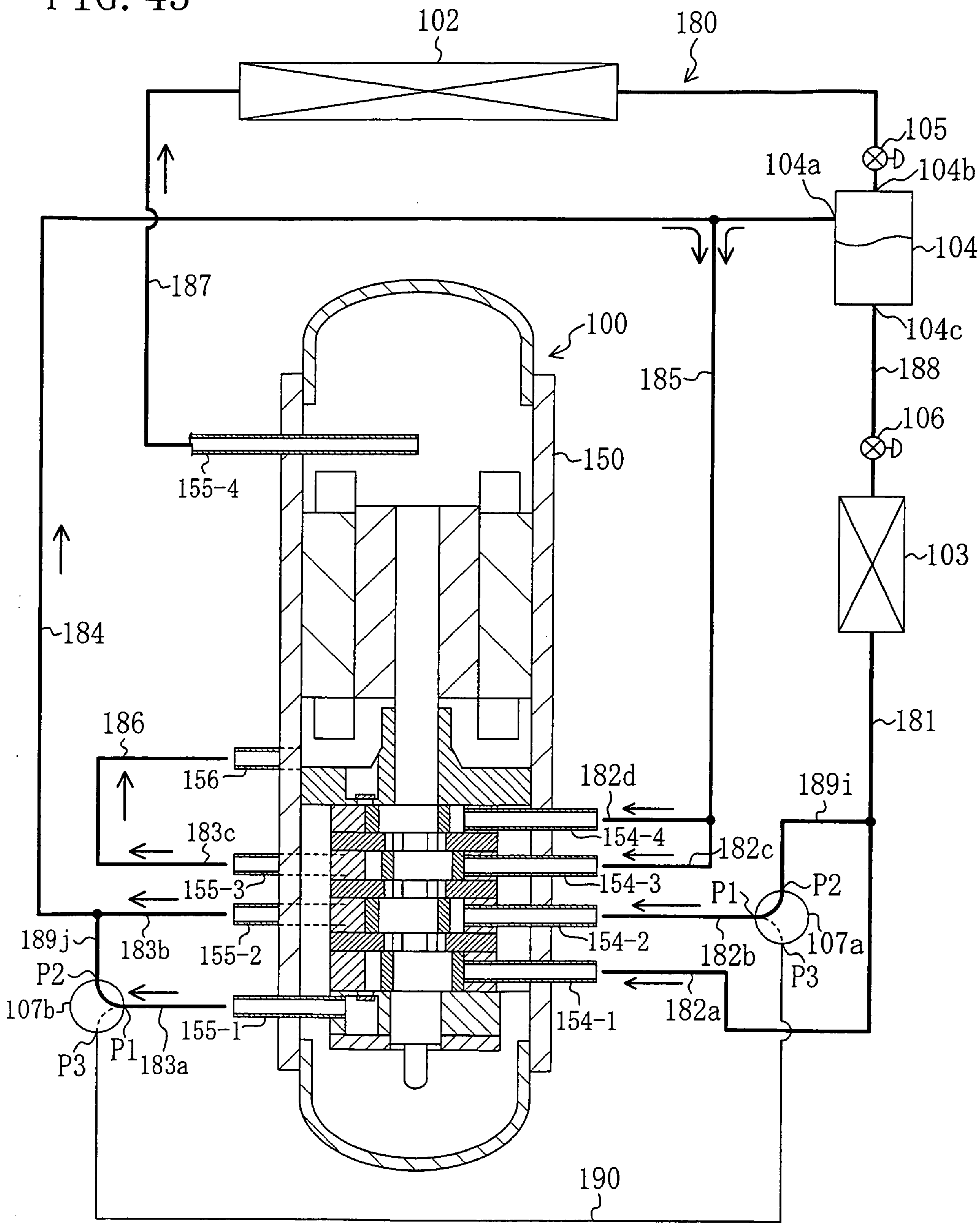
182d
183c
154-4
182c
155-3
154-3
P1
P3
107
183b
155-2
154-2
182b
P2
189h
182a
155-1
154-1
183a

FIG. 42



102
180
105
104a
104b
104
187
100
104c
185
188
106
150
155-4
103
184
181
186
156
182d
154-4
183c
182c
155-3
154-3
P1
P3
107
183b
155-2
154-2
182b
P2
189h
155-1
154-1
182a
183a

FIG. 43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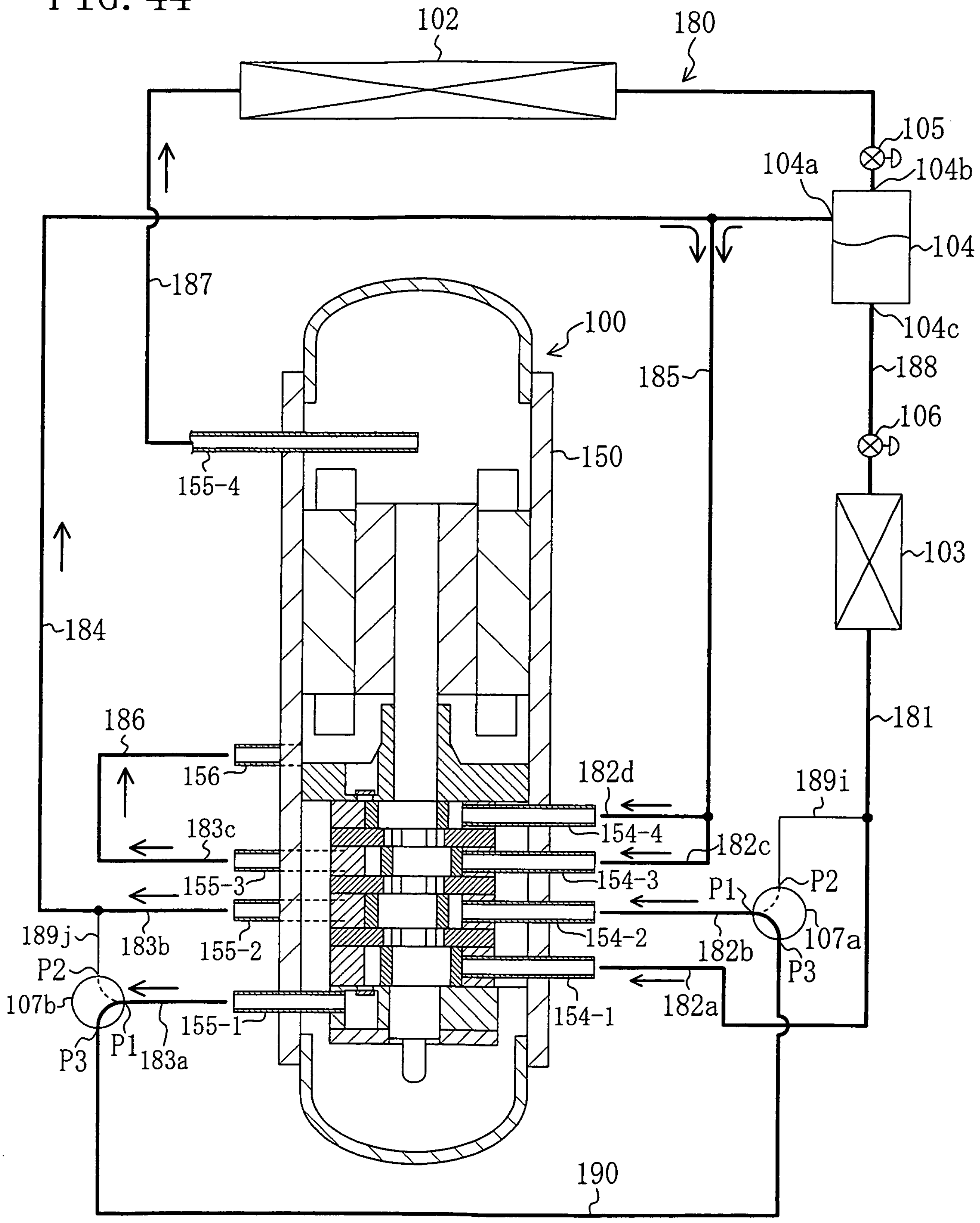
182d
189i
154-4
183c
182c
155-3
154-3
P1
P2
189j
183b
155-2
154-2
182b
107a
P2
P3
107b
155-1
154-1
182a
P3
P1
183a
190

FIG. 44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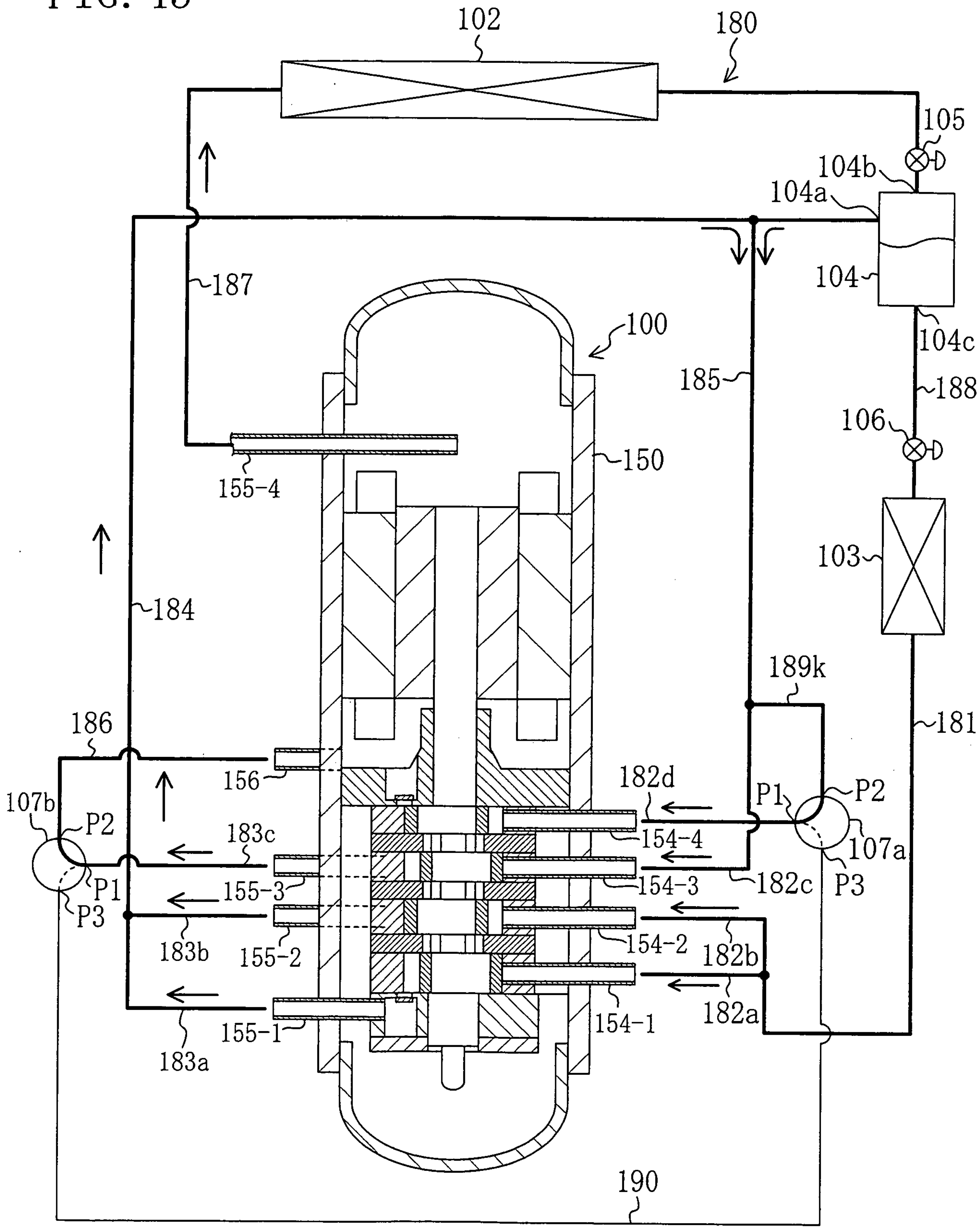
182d
189i
154-4
183c
182c
155-3
154-3
P1
P2
155-2
154-2
107a
189j
183b
182b
P3
P2
107b
155-1
154-1
182a
P3
P1
183a
190

FIG. 45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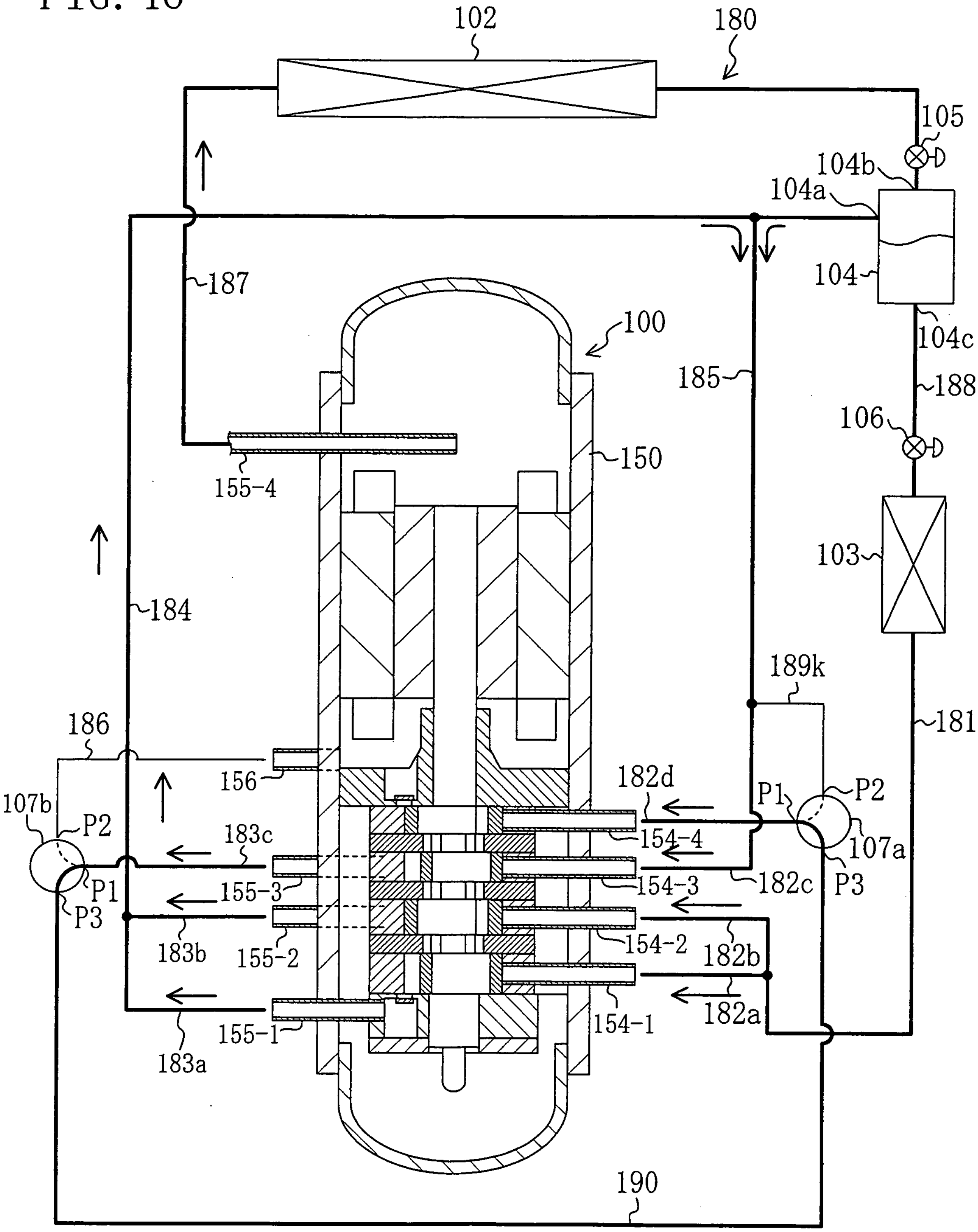
182d
P1
P2
107a
P3
107b
P2
183c
154-4
154-3
182c
155-3
P1
P3
155-2
154-2
182b
183b
182a
154-1
155-1
183a
190

FIG. 46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104c
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100
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155-4
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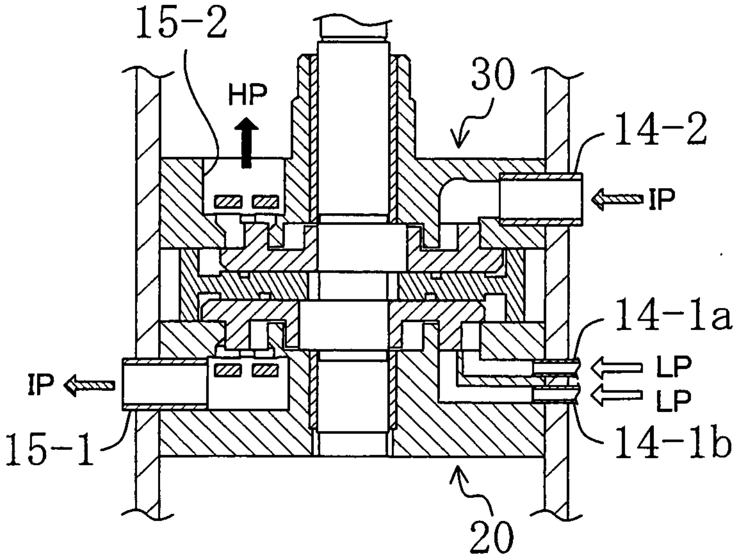
189k
186
156
182d
P1
P2
107b
P2
183c
154-4
107a
P1
155-3
154-3
182c
P3
P3
155-2
154-2
182b
183b
155-1
154-1
182a
183a
190

FIG. 47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14-2
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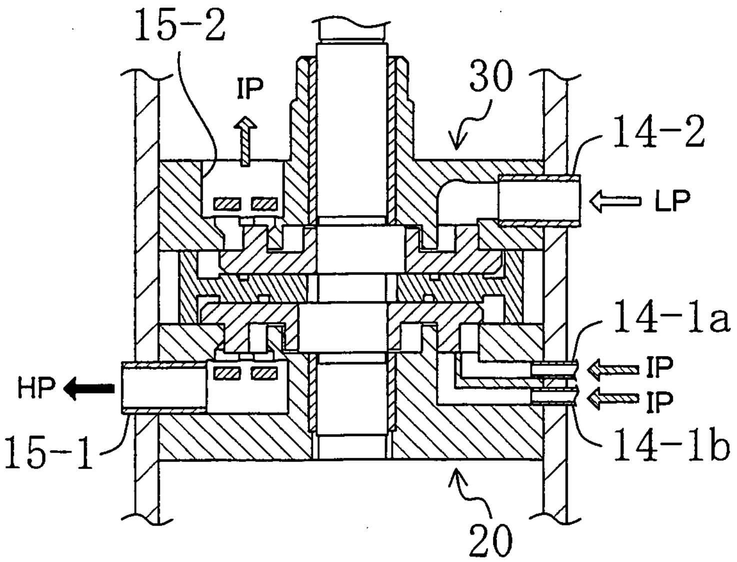
14-1a
LP
LP
IP
15-1
14-1b
20

FIG. 48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14-2
LP
14-1a
IP
IP
HP
15-1
14-1b
20

FIG. 49

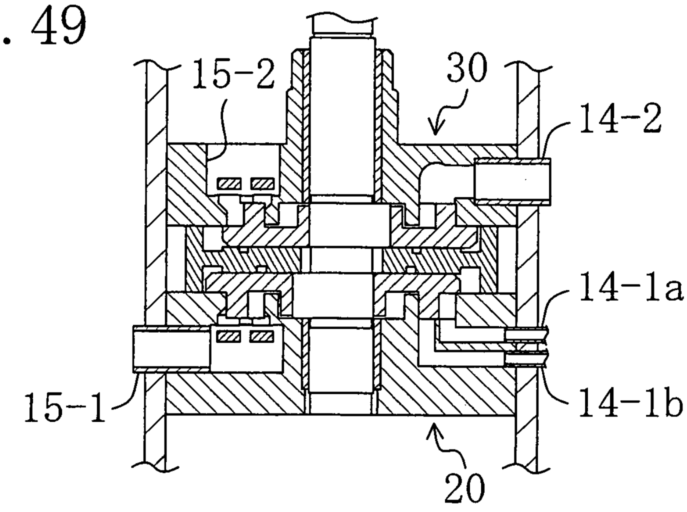


FIG. 50

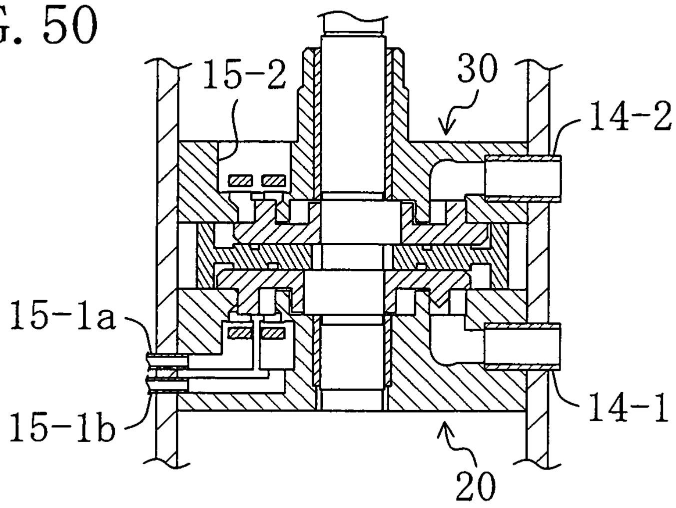


FIG. 51

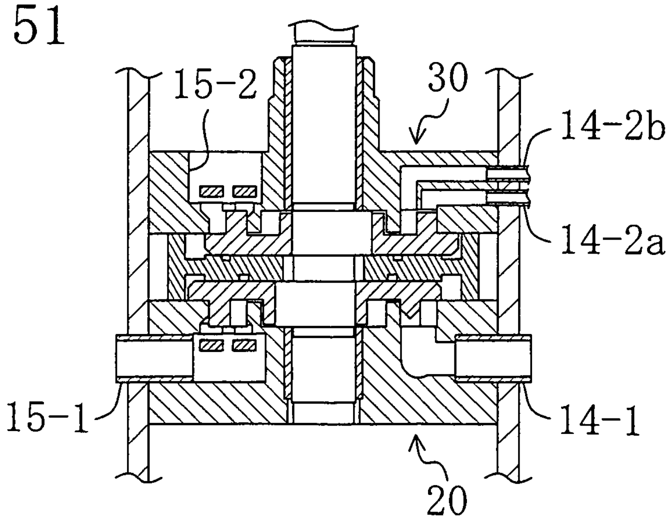


FIG. 52

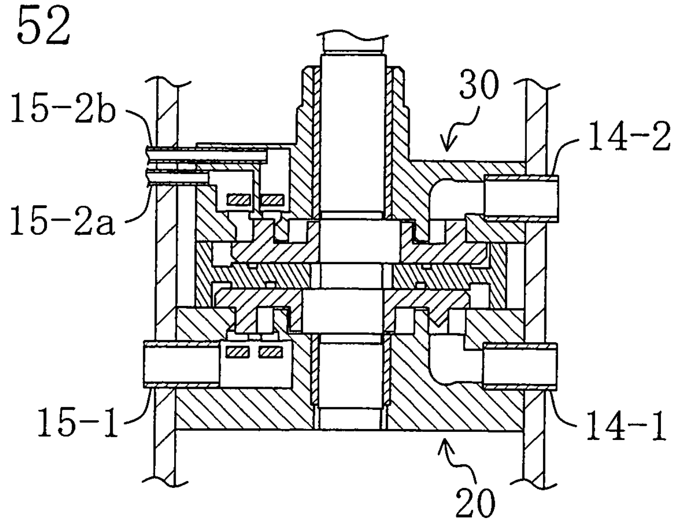


FIG. 53

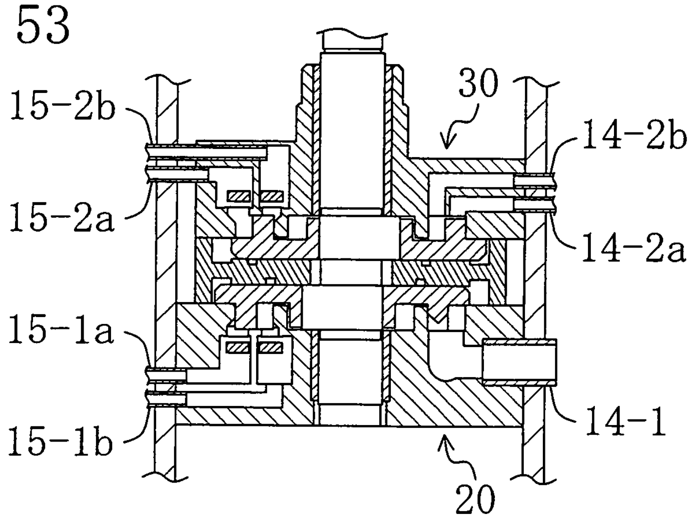


FIG. 54

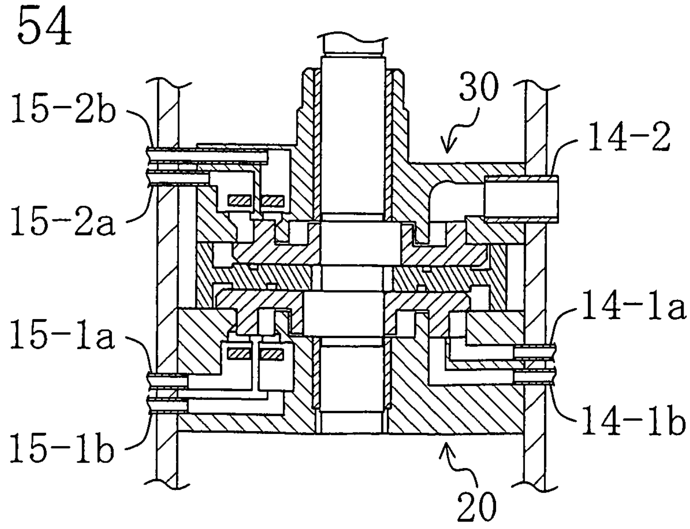


FIG. 55

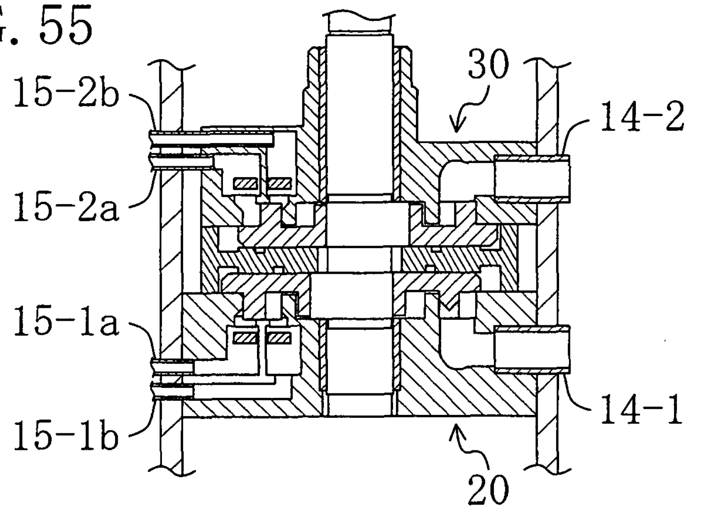


FIG. 56

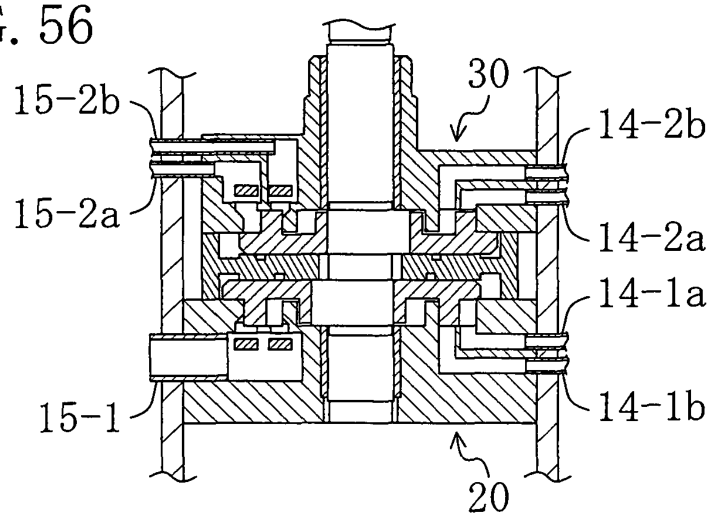


FIG. 57

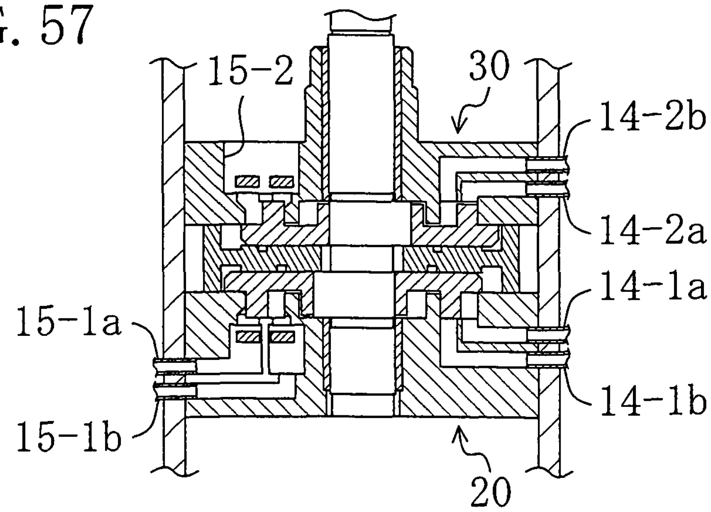


FIG. 58

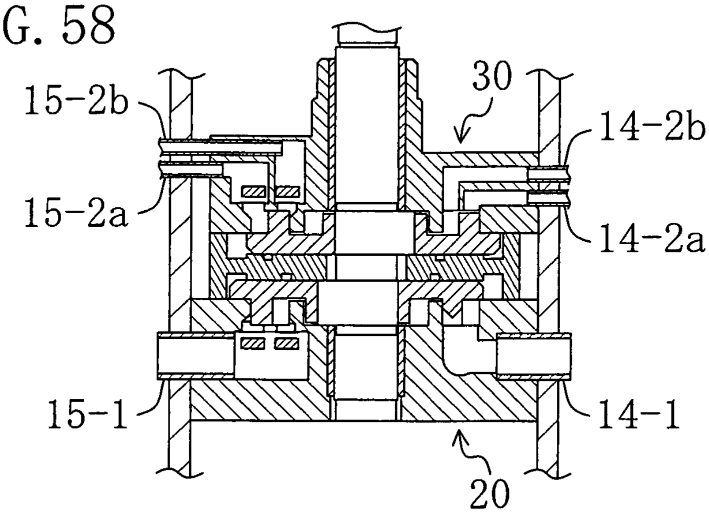


FIG. 59

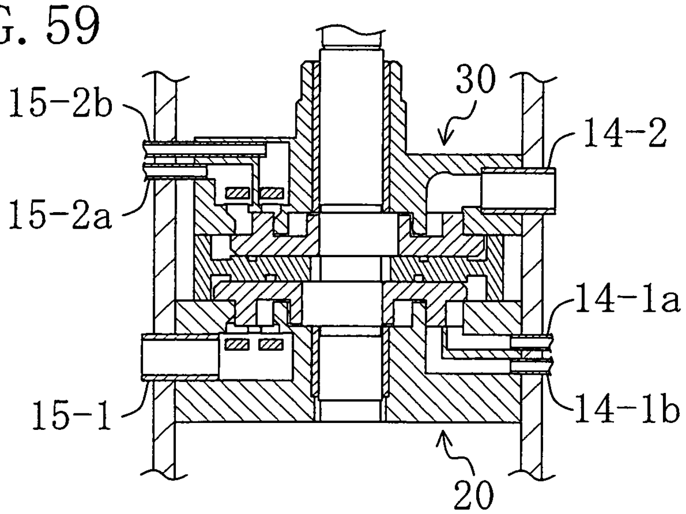


FIG. 60

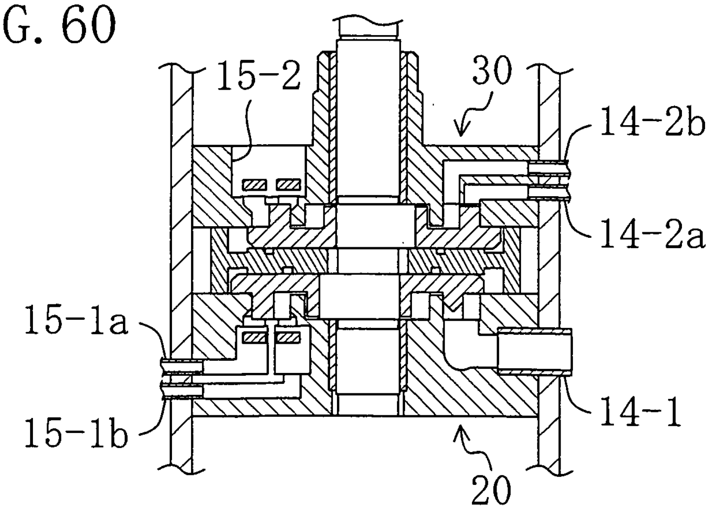


FIG. 61

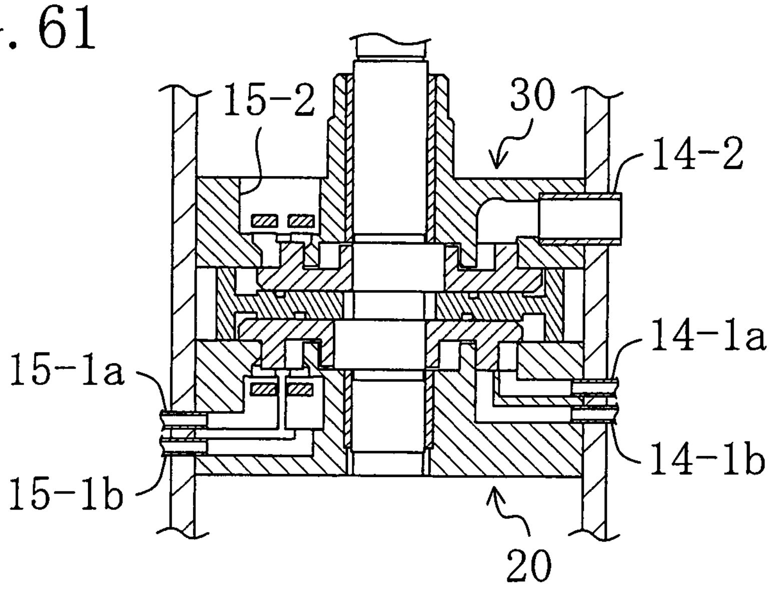
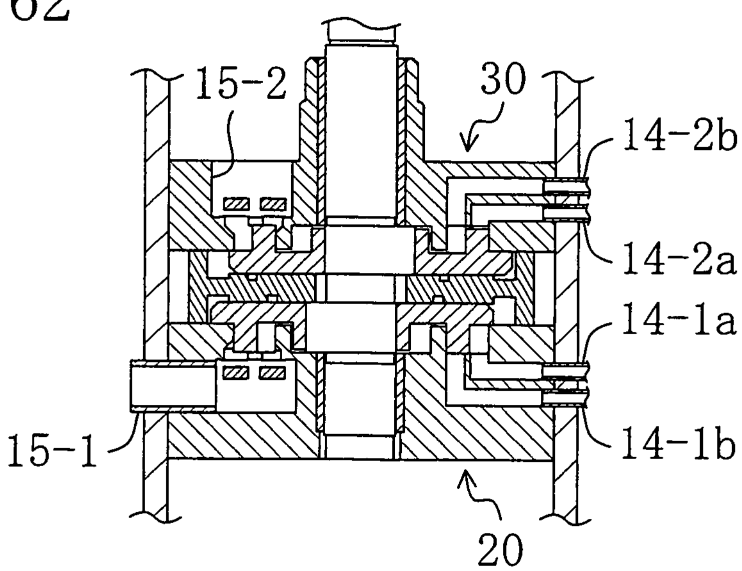

15-2
30
14-2
14-1a
15-1a
14-1b
15-1b
20

FIG. 62


15-2
30
14-2b
14-2a
14-1a
15-1
14-1b
20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004443

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/10(2006.01)i, *F04C18/32*(2006.01)i, *F04C23/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B1/10, F04C18/32, F04C23/00

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	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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.
Y	JP 2007-239666 A (Daikin Industries, Ltd.), 20 September 2007 (20.09.2007), entire text; fig. 1 to 13 & US 2009/0013714 A1 & EP 1992820 A1 & WO 2007/102496 A1 & KR 10-2008-0087894 A & CN 101389867 A	1-3,9-13,17, 21-23
Y	JP 2007-232280 A (Daikin Industries, Ltd.), 13 September 2007 (13.09.2007), paragraphs [0091] to [0099]; fig. 7 (Family: none)	1-3,9-13,17, 21-23
Y	WO 2008/087887 A1 (Daikin Industries, Ltd.), 24 July 2008 (24.07.2008), paragraphs [0039] to [0147]; fig. 1 to 12 & JP 2008-175111 A	1-3,9-13,17, 21-23

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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

Date of the actual completion of the international search	Date of mailing of the international search report
10 December, 2009 (10.12.09)	22 December, 2009 (22.12.09)

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

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004443

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 2003-148365 A (Sanyo Electric Co., Ltd.), 21 May 2003 (21.05.2003), paragraphs [0009] to [0024]; fig. 1 to 5 (Family: none)	1-3,9-13,17, 21-23
Y	JP 10-141270 A (Matsushita Electric Industrial Co., Ltd.), 26 May 1998 (26.05.1998), paragraphs [0028] to [0123]; fig. 1 to 12 (Family: none)	1-3,9-13,17, 21-23

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004443

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 result of the search has revealed that the invention in claim 1 is constituted by the addition, the conversion, etc. of a well-known art or a commonly used art onto the technique described in document 1 or document 2 (if necessary, see document 3 to document 5), and does not provide a novel effect. Therefore, the common matter is not a special technical feature in the meaning of the second sentence of PCT rule 13.2.

Although the unity of invention is not requested exceptionally for the inventions in claims 2, 3, 9-13, 17, 21-23 according to the examination standards (continued to extra sheet)

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: 1-3, 9-13, 17, 21-23

Remark on Protest

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

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

☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2009/004443

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

(See Paragraph 4.2, Chapter 2, Section I of "Patent and Utility Model Examination Standards"), for the inventions in claims 4-8, 14-16, 18-20, any technical relation in the meaning of PCT rule 13 cannot be found among the these different inventions since any other common matter considered to be a special technical feature in claim 1 and the meaning of the second sentence of PCT rule 13.2 is not present.

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2007023993 A **[0003]**