(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 350 246 A1

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

(43) Date of publication:
10.04.2024 Bulletin 2024/15

(21) Application number: **21942944.6**

(22) Date of filing: **25.05.2021**

(51) International Patent Classification (IPC):
F25B 1/00 $^{(2006.01)}$ ***F25B 1/10*** $^{(2006.01)}$

(52) Cooperative Patent Classification (CPC):
F25B 1/00; F25B 1/10

(86) International application number:
PCT/JP2021/019830

(87) International publication number:
WO 2022/249289 (01.12.2022 Gazette 2022/48)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(71) Applicant: **MITSUBISHI ELECTRIC CORPORATION**
Chiyoda-ku
Tokyo 100-8310 (JP)

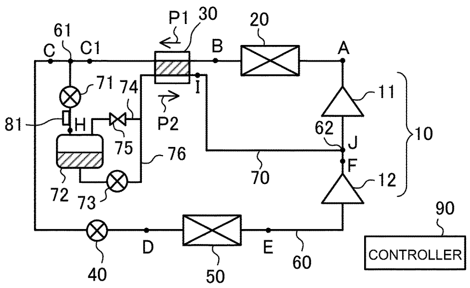
(72) Inventors:
- **ISHIKAWA, Tomotaka**
  Tokyo 1008310 (JP)
- **ARII, Yusuke**
  Tokyo 1008310 (JP)
- **UEDA, Kohei**
  Tokyo 1008310 (JP)
- **HAYASAKA, Motoshi**
  Tokyo 1008310 (JP)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Joachimsthaler Straße 10-12
10719 Berlin (DE)

(54) REFRIGERATION CYCLE DEVICE

(57) A refrigeration cycle apparatus includes a controller, a compressor configured to compress refrigerant to cause a pressure of the refrigerant to rise from a first pressure to a second pressure higher than the first pressure, a condenser configured to cause heat exchange to be performed between air and the refrigerant discharged from the compressor, an INJ branch unit configured to cause the refrigerant that flows out of the condenser to branch into first refrigerant and second refrigerant, an expansion valve configured to expand the first refrigerant that flows out of the INJ branch unit to reduce a pressure of the first refrigerant to the first pressure, an evaporator configured to cause heat exchange to be performed between air and the first refrigerant that flows out of the expansion valve, and cause the first refrigerant having the first pressure to flow to the compressor, and an injection circuit connected between the INJ branch unit and the compressor, and configured to cause the second refrigerant that flows out of the INJ branch unit to flow to the compressor. The injection circuit includes an INJ expansion valve configured to expand the second refrigerant to reduce a pressure of the second refrigerant to an intermediate pressure that is higher than the first pressure and lower than the second pressure, and a receiver configured to store the second refrigerant that flows out of the INJ expansion valve, and cause the second refrigerant having the intermediate pressure to flow to the compressor. The controller is configured to control at least one of a rotating speed of the compressor and an opening degree of the INJ expansion valve such that the intermediate pressure, which corresponds to an internal pressure of the receiver, falls to or below a first threshold or is kept constant within a first range.

FIG. 1



EP 4 350 246 A1

Description

Technical Field

[0001] The present disclosure relates to a refrigeration cycle apparatus having an intermediate pressure receiver.

Background Art

[0002] A multistage compression refrigeration cycle apparatus including a low-stage compressor and a high-stage compressor that performs two-stage compression not to excessively reduce the pressure in an outdoor heat exchanger even when the outside air temperature is low is known (see, for example, Patent Literature 1).

[0003] In the refrigeration cycle apparatus described in Patent Literature 1, a low-stage compressor, a high-stage compressor, a use-side heat exchanger, a use-side expansion valve, a receiver, a subcooling heat exchanger, an expansion valve, and an outdoor heat exchanger are connected by refrigerant pipes.

[0004] The low-stage compressor compresses sucked refrigerant from a low pressure to an intermediate pressure. The high-stage compressor compresses the refrigerant having an intermediate pressure discharged from the low-stage compressor to a high pressure. The refrigerant discharged from the high-stage compressor flows into the use-side heat exchanger. The refrigerant condensed and liquefied in the use-side heat exchanger passes through the use-side expansion valve, thereby being decompressed. The decompressed refrigerant flows into the receiver.

[0005] In the receiver, the refrigerant in a gas state and the refrigerant in a liquid state are separated from each other. The refrigerant in a liquid state separated in the receiver is divided at a branch point. Part of the refrigerant in a liquid state (hereinafter referred to as first refrigerant) is guided to the subcooling heat exchanger provided on the downstream side of the branch point. Meanwhile, the remaining part of the refrigerant in a liquid state (hereinafter referred to as second refrigerant) is expanded by the subcooling expansion valve and then guided to the subcooling heat exchanger. In the subcooling heat exchanger, the second refrigerant cools the first refrigerant and applies subcooling to the first refrigerant. The second refrigerant that has applied subcooling to the first refrigerant and has been gasified is guided between the discharge side of the low-stage compressor and the suction side of the high-stage compressor via an intermediate pressure injection line.

[0006] Meanwhile, the first refrigerant on which subcooling has been applied is guided to the expansion valve. The first refrigerant expanded by the expansion valve enters a low-pressure state and flows into the outdoor heat exchanger. In the outdoor heat exchanger, heat is exchanged between the first refrigerant and the outside air, and the first refrigerant is thereby evaporated. The first refrigerant that is evaporated and gasified in the outdoor heat exchanger is sucked into the low-stage compressor.

Citation List

Patent Literature

[0007] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2018-21732

Summary of Invention

Technical Problem

[0008] There are two types of refrigerant, a simple composition refrigerant and a refrigerant mixture in which a plurality of refrigerants are mixed. When a plurality of refrigerant components are mixed in a certain ratio, a refrigerant mixture that has a constant boiling point, has the same composition in the gas phase and the liquid phase, and changes its phase as if the refrigerant mixture is a single component may be obtained. Such a refrigerant mixture is called "azeotropic refrigerant mixture".

[0009] On the other hand, a refrigerant mixture that acts just like a mixture of refrigerants having different dew points and different boiling points in the whole composition range is called "zeotropic refrigerant mixture". When a zeotropic refrigerant mixture is used in a refrigeration cycle apparatus, the composition varies constantly. Especially when leakage of the refrigerant occurs, the composition changes from the composition of the original mixture ratio. Examples of the zeotropic refrigerant mixture include R404A, R407C, and R463A. R463A is a carbon dioxide (CO_2) refrigerant mixture in which CO_2 is mixed. Among the zeotropic refrigerant mixtures, a CO_2 refrigerant mixture, in particular, causes a significant composition change.

[0010] Patent Literature 1 indicates that R134a or R1234yf is used as refrigerant but does not indicate an intention to use a zeotropic refrigerant mixture.

[0011] However, in the refrigeration cycle apparatus that has the receiver connected to the intermediate pressure injection line as described in Patent Literature 1, when a zeotropic refrigerant is used, the gas density in the receiver varies according to the intermediate pressure. That is, because the pressure in the receiver is an intermediate pressure, when the intermediate pressure increases, the gas density in the receiver increases and the mass of the refrigerant in a gas state increases. Meanwhile, when the intermediate pressure decreases, the gas density in the receiver decreases and the mass of the refrigerant in a gas state decreases. In this case, given that the receiver has a fixed volume, the mass of the refrigerant in a liquid state varies according to the mass of the refrigerant in a gas state, and consequently the composition of circulating refrigerant, which is the refrigerant circulating in the refrigerant circuit, is changed.
[0012] Because the refrigerant in a liquid state circulates in the refrigerant circuit, when such variation in the gas density occurs in the receiver, the composition of the circulating refrigerant changes and variation in the capacity of the refrigeration cycle apparatus occurs. As a result, in some cases, there is a possibility that insufficiency of cooling occurs in an evaporator of the refrigeration cycle apparatus.
[0013] The present disclosure has been made to solve the problem described above, and has an object to obtain a refrigeration cycle apparatus capable of reducing or eliminating variation in the intermediate pressure in the receiver, reducing or eliminating variation in the composition of the circulating refrigerant, and preventing insufficient cooling from occurring in the refrigeration cycle apparatus.

Solution to Problem

[0014] A refrigeration cycle apparatus according to an embodiment of the present disclosure includes a controller, a compressor configured to compress refrigerant to cause a pressure of the refrigerant to rise from a first pressure to a second pressure higher than the first pressure, a condenser configured to cause heat exchange to be performed between air and the refrigerant discharged from the compressor, an INJ branch unit configured to cause the refrigerant that flows out of the condenser to branch into first refrigerant and second refrigerant, an expansion valve configured to expand the first refrigerant that flows out of the INJ branch unit to reduce a pressure of the first refrigerant to the first pressure, an evaporator configured to cause heat exchange to be performed between air and the first refrigerant that flows out of the expansion valve, and cause the first refrigerant having the first pressure to flow to the compressor, and an injection circuit connected between the INJ branch unit and the compressor, and configured to cause the second refrigerant that flows out of the INJ branch unit to flow to the compressor. The injection circuit includes an INJ expansion valve configured to expand the second refrigerant to reduce a pressure of the second refrigerant to an intermediate pressure that is higher than the first pressure and lower than the second pressure, and a receiver configured to store the second refrigerant that flows out of the INJ expansion valve, and cause the second refrigerant having the intermediate pressure to flow to the compressor. The controller is configured to control at least one of a rotating speed of the compressor and an opening degree of the INJ expansion valve such that the intermediate pressure, which corresponds to an internal pressure of the receiver, falls to or below a first threshold or is kept constant within a first range. Advantageous Effects of Invention
[0015] With the refrigeration cycle apparatus according to an embodiment of the present disclosure, variation in the intermediate pressure in the receiver is reduced or eliminated, variation in the composition of circulating refrigerant is reduced or eliminated, and thus insufficient cooling can be prevented from occurring in the refrigeration cycle apparatus.

Brief Description of Drawings

[0016]

[Fig. 1] Fig. 1 is a refrigerant circuit diagram illustrating the configuration of a refrigeration cycle apparatus according to Embodiment 1.
[Fig. 2] Fig. 2 is a perspective view illustrating an example of the configuration of a heat inter changer (HIC) 30 provided in the refrigeration cycle apparatus according to Embodiment 1.
[Fig. 3] Fig. 3 is a pressure-enthalpy (p-h) diagram illustrating a refrigeration cycle of the refrigeration cycle apparatus according to Embodiment 1.
[Fig. 4] Fig. 4 is a flowchart illustrating a flow of processing in a control method (M1).
[Fig. 5] Fig. 5 is a flowchart illustrating a flow of processing in a control method (M2).
[Fig. 6] Fig. 6 is a flowchart illustrating a flow of processing when processing (a1) and processing (a2) are performed as a first processing and a second processing in the flow of Fig. 5.
[Fig. 7] Fig. 7 is a flowchart illustrating a flow of processing when processing (b1) and processing (b2) are performed as the first processing and the second processing in the flow of Fig. 5.
[Fig. 8] Fig. 8 is a refrigerant circuit diagram illustrating the configuration of a modified example of the refrigeration cycle apparatus according to Embodiment 1.
[Fig. 9] Fig. 9 is an explanatory diagram schematically illustrating the configuration of a low-stage compressor 12

and a high-stage compressor 11 of Fig. 1.

[Fig. 10] Fig. 10 is an explanatory diagram schematically illustrating the configuration of an injection compressor 13 of Fig. 8.

Description of Embodiments

[0017] An embodiment of the refrigeration cycle apparatus according to the present disclosure is described below with reference to the drawings. The present disclosure is not limited to the embodiment below, and various modifications can be made without departing from the scope of the present disclosure. Furthermore, the present disclosure includes any combination of features that can be combined with each other among the features shown in the embodiment and its modified example described below. Moreover, in the drawings, components denoted by the same reference signs are the same or corresponding components, and this applies to the entire description. In addition, in the drawings, the relationship of relative sizes of components or the shape of each component may differ from actual one.

Embodiment 1

[0018] Fig. 1 is a refrigerant circuit diagram illustrating the configuration of a refrigeration cycle apparatus according to Embodiment 1. As shown in Fig. 1, the refrigeration cycle apparatus includes, as a main circuit, a refrigerant circuit in which a compressor 10, a condenser 20, an heat inter changer (HIC) 30, an expansion valve 40, and an evaporator 50 are connected by a refrigerant pipe 60. The compressor 10 includes a high-stage compressor 11 and a low-stage compressor 12. The refrigeration cycle apparatus is used as, for example, a refrigeration apparatus, but is not limited to this usage.

[0019] In addition, the refrigeration cycle apparatus includes an injection circuit 70, as shown in Fig. 1. The injection circuit 70 is an intermediate pressure refrigerant bypass circuit for causing refrigerant having an intermediate pressure P_M, which will be described later, to flow. Furthermore, as shown in Fig. 1, an INJ branch unit 61 is provided between the heat inter changer (HIC) 30 and the expansion valve 40. In addition, an INJ junction unit 62 is provided between a discharge side of the low-stage compressor 12 and a suction side of the high-stage compressor 11. One end of the injection circuit 70 is connected to the INJ branch unit 61 and the other end of the injection circuit 70 is connected to the INJ junction unit 62.

[0020] The injection circuit 70 is formed by connecting an INJ expansion valve 71, a receiver 72, and a flow control valve 73 by an injection pipe 76. Furthermore, the injection circuit 70 may be provided with a gas vent pipe 74. The gas vent pipe 74 is a bypass pipe connected between the receiver 72 and the injection pipe 76. The gas vent pipe 74 may be provided with an on-off valve 75.

[0021] In the main circuit, refrigerant flows in the refrigerant pipe 60 through the low-stage compressor 12, the INJ junction unit 62, the high-stage compressor 11, the condenser 20, the heat inter changer (HIC) 30, the INJ branch unit 61, the expansion valve 40, and the evaporator 50 in this order.

[0022] Furthermore, in the injection circuit 70, refrigerant flows in the injection pipe 76 through the INJ branch unit 61, the INJ expansion valve 71, the receiver 72, the flow control valve 73, the heat inter changer (HIC) 30, and the INJ junction unit 62 in this order.

[0023] Configurations of the devices forming the refrigeration cycle apparatus shown in Fig. 1 will be described below.

[0024] The low-stage compressor 12 is configured to compress sucked refrigerant to cause the pressure of the refrigerant to rise from a low pressure P_L to an intermediate pressure P_M, and discharge the refrigerant. The low-stage compressor 12 is, for example, an inverter compressor. When the low-stage compressor 12 is an inverter compressor, the rotating speed may be changed to any speed by a driving circuit, such as an inverter circuit, to change the volume of refrigerant delivered by the low-stage compressor 12 per unit time. In this case, the driving circuit is controlled by a controller 90. Note that, the low pressure P_L is a first pressure set in advance.

[0025] The high-stage compressor 11 is configured to compress the refrigerant having the intermediate pressure P_M discharged from the low-stage compressor 12 and the refrigerant having the intermediate pressure P_M that flows in from the injection circuit 70 to cause the pressure of the refrigerant to rise to a high pressure P_H. The refrigerant discharged from the high-stage compressor 11 flows into the condenser 20. The high-stage compressor 11 is, for example, an inverter compressor. When the high-stage compressor 11 is an inverter compressor, the rotating speed may be changed to any speed by a driving circuit, such as an inverter circuit, to change the volume of refrigerant delivered by the high-stage compressor 11 per unit time. In this case, the driving circuit is controlled by the controller 90. Note that, the high pressure P_H is a second pressure set in advance. The second pressure is higher than the first pressure. In addition, the intermediate pressure P_M is higher than the first pressure and lower than the second pressure.

[0026] The condenser 20 is provided outdoors, for example. The condenser 20 is a heat exchanger that performs heat exchange between refrigerant flowing in the heat exchanger and air. The condenser 20 is, for example, a fin-and-tube type heat exchanger. The refrigerant condensed and liquefied in the condenser 20 flows into the heat inter changer

(HIC) 30.

[0027] The heat inter changer (HIC) 30 is configured to perform inter-refrigerant heat exchange to cool one refrigerant by the other refrigerant. As shown in Fig. 2, the heat inter changer (HIC) 30 is formed by a double pipe. Fig. 2 is a perspective view illustrating an example of the configuration of the heat inter changer (HIC) 30 provided in the refrigeration cycle apparatus according to Embodiment 1. In Fig. 2, part of the configuration is transparently represented by broken lines for the purpose of explanation. In the example of Fig. 2, the heat inter changer (HIC) 30 includes an outer pipe 31 provided on an outer side and an inner pipe 32 provided inside the outer pipe 31. The refrigerant that flows out of the condenser 20 flows in the outer pipe 31 in the direction of arrows P1 of Fig. 2. The refrigerant flowing in the injection pipe 76 flows in the inner pipe 32 in the direction of arrow P2 of Fig. 2. As shown by the arrows in Fig. 2, the direction (direction of arrows P1) in which the refrigerant flows in the outer pipe 31 and the direction (direction of arrow P2) in which the refrigerant flows in the inner pipe 32 are opposite to each other, and the flows of the refrigerant face each other. Note that, the heat inter changer (HIC) 30 is not limited to the example of Fig. 2. For example, the refrigerant flowing in the injection pipe 76 may flow in the outer pipe 31, and the refrigerant that flows out of the condenser 20 may flow in the inner pipe 32. In addition, the heat inter changer (HIC) 30 may be of another configuration.

[0028] In the heat inter changer (HIC) 30, the refrigerant (second refrigerant, which will be described later) that flows out of the receiver 72 and flows in the injection pipe 76 cools the refrigerant that flows out of the condenser 20 and applies subcooling to the refrigerant that flows out of the condenser 20. The refrigerant (second refrigerant) that has applied subcooling and has gasified continues to flow in the injection pipe 76, and is guided to the INJ junction unit 62. As described above, the INJ junction unit 62 is provided between the discharge side of the low-stage compressor 12 and the suction side of the high-stage compressor 11.

[0029] Meanwhile, the refrigerant on which subcooling has been applied in the heat inter changer (HIC) 30 is branched into first refrigerant and second refrigerant at the INJ branch unit 61. The first refrigerant branched at the INJ branch unit 61 flows in the refrigerant pipe 60 and is guided to the expansion valve 40. The expansion valve 40 is configured to expand the first refrigerant to reduce the pressure of the first refrigerant. The first refrigerant that is expanded and caused to have the low pressure P_L flows into the evaporator 50. The expansion valve 40 is, for example, an electronic expansion valve. When the expansion valve 40 is formed by an electronic expansion valve, the opening degree is controlled by the controller 90 to be adjusted.

[0030] The evaporator 50 is provided in an indoor space, for example. The evaporator 50 is a heat exchanger that performs heat exchange between the refrigerant flowing in the heat exchanger and air. The evaporator 50 is, for example, a fin-and-tube type heat exchanger. In the evaporator 50, heat exchange is performed between the first refrigerant and air, and the first refrigerant is evaporated. The first refrigerant that is evaporated and gasified is sucked into the low-stage compressor 12. The low-stage compressor 12 sucks the refrigerant having the low pressure P_L that flows out of the evaporator 50, compresses the refrigerant to cause the pressure of the refrigerant to rise to the intermediate pressure P_M, and discharges the refrigerant.

[0031] Meanwhile, the second refrigerant branched at the INJ branch unit 61 flows in the injection pipe 76 and flows into the INJ expansion valve 71 first.

[0032] The INJ expansion valve 71 is configured to expand the second refrigerant and thus reduce the pressure of the second refrigerant. The second refrigerant expanded and caused to have the intermediate pressure P_M flows into the receiver 72. The INJ expansion valve 71 is, for example, an electronic expansion valve. When the INJ expansion valve 71 is formed by an electronic expansion valve, the opening degree is controlled by the controller 90 to be adjusted.

[0033] The receiver 72 is configured to store the second refrigerant that is expanded by the INJ expansion valve 71 and caused to have the intermediate pressure P_M. In the receiver 72, the second refrigerant is separated into the refrigerant in a liquid state and the refrigerant in a gas state. The refrigerant in a liquid state separated in the receiver 72 flows into the inner pipe 32 of the heat inter changer (HIC) 30 via the injection pipe 76. The second refrigerant flowing in the inner pipe 32 exchanges heat with the refrigerant flowing in the outer pipe 31, and then is guided to the INJ junction unit 62.

[0034] At this time, in the heat inter changer (HIC) 30, the second refrigerant cools the refrigerant flowing in the outer pipe 31 and applies subcooling to the refrigerant flowing in the outer pipe 31.

[0035] The injection pipe 76 between the receiver 72 and the heat inter changer (HIC) 30 is provided with the flow control valve 73. The flow rate of the second refrigerant flowing out of the receiver 72 is controlled according to the opening degree of the flow control valve 73. The flow control valve 73 is, for example, an electronic control valve. In this case, the opening degree of the flow control valve 73 is controlled by the controller 90. However, the flow control valve 73 is not necessarily required, and may be installed only when needed. In addition, the heat inter changer (HIC) 30 is not necessarily required, and may be installed only when needed.

[0036] In the INJ junction unit 62, the second refrigerant having the intermediate pressure P_M flowing in the injection pipe 76 and the first refrigerant having the intermediate pressure P_M discharged by the low-stage compressor 12 are joined together. The refrigerant joined at the INJ junction unit 62 is sucked into the high-stage compressor 11. The high-stage compressor 11 compresses the sucked refrigerant from the intermediate pressure P_M to the high pressure P_H, and discharged the refrigerant.

[0037] The gas vent pipe 74 is a bypass pipe connected between the receiver 72 and the injection pipe 76. One end of the gas vent pipe 74 is connected to an upper part of the receiver 72, and the other end of the gas vent pipe 74 is connected between the flow control valve 73 and the heat inter changer (HIC) 30. When the on-off valve 75 is in an open state, the gas vent pipe 74 causes the refrigerant in a gas state in the receiver 72 to flow into the injection pipe 76. When the on-off valve 75 is in a closed state, the gas vent pipe 74 stops the outflow of the refrigerant in a gas state in the receiver 72. With this configuration, the composition of the refrigerant flowing in the injection circuit 70, that is, the gas density of the refrigerant can be finely adjusted. Note, however, that the gas vent pipe 74 is not necessarily required, and may be installed only when needed.

[0038] The controller 90 includes a processing circuit. The processing circuit is dedicated hardware or a processor. The dedicated hardware is, for example, an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a similar circuit. The processor is configured to execute a program stored in the memory. Storage circuitry (not shown) provided in the controller 90 is formed by a memory. The memory is, for example, a non-volatile or volatile semiconductor memory, such as a random access memory (RAM), a read only memory (ROM), a flash memory, and an erasable programmable ROM (EPROM), or a disk, such as a magnetic disk, a flexible disk, and an optical disk.

[0039] Furthermore, as shown in Fig. 1, a pressure sensor 81 configured to measure an intermediate pressure P_M is provided between the INJ expansion valve 71 and the receiver 72 in Embodiment 1. An intermediate pressure P_M detected by the pressure sensor 81 is transmitted to the controller 90. The intermediate pressure P_M is an internal pressure of the receiver 72.

[0040] Fig. 3 is a p-h diagram illustrating a refrigeration cycle of the refrigeration cycle apparatus according to Embodiment 1. In Fig. 3, the horizontal axis represents specific enthalpy, and the vertical axis represents pressure of the refrigerant. Note that, points A to J in Fig. 3 correspond to the points shown in the refrigerant circuit diagram of Fig. 1. In addition, point C and point C1 are actually the same point, but are represented as slightly displaced points for the purpose of explanation.

[0041] First, the high-stage compressor 11 sucks the refrigerant having the intermediate pressure P_M (state of point J) and compresses the refrigerant to the high pressure P_H (state of point A). The refrigerant in a high-temperature and high-pressure gas state (state of point A) discharged from the high-stage compressor 11 flows into the condenser 20. In the condenser 20, the refrigerant in a high-temperature and high-pressure gas state rejects heat to air, is thus condensed and liquefied, and then the refrigerant enters a liquid state having the high pressure P_H (state of point B). The refrigerant in a high-pressure liquid state passes through the heat inter changer (HIC) 30 in a direction of arrow P1 of Fig. 1, and enters a state in which the degree of subcooling is increased further (states of points C and C1). Part of the refrigerant (state of point C1) that has passed through the heat inter changer (HIC) 30 flows into the INJ expansion valve 71 via the INJ branch unit 61. In the INJ expansion valve 71, the refrigerant in a liquid state having the high pressure P_H is decompressed to the intermediate pressure P_M. Then, the refrigerant flows into the receiver 72, and enters a two-phase gas-liquid state (state of point H). Then, the refrigerant in a liquid state that flows out of the receiver 72 passes through the heat inter changer (HIC) 30 in a direction of arrow P2, which is opposite to the direction of arrow P1. As a result, the refrigerant enters a two-phase state having the intermediate pressure P_M and an increased temperature (state of point I).

[0042] Meanwhile, the remaining part of the refrigerant (state of point C) that has passed through the heat inter changer (HIC) 30 flows into the expansion valve 40. In the expansion valve 40, the refrigerant in a liquid state having the high pressure P_H is decompressed to the low pressure P_L, and enters a two-phase gas-liquid state (state of point D). Then, the refrigerant in a two-phase state having the low pressure P_L (state of point D) flows into the evaporator 50. In the evaporator 50, the refrigerant in a two-phase state having the low pressure P_L receives heat from air and is thus evaporated, and then enters a gas state having the low pressure P_L (state of point E). The refrigerant in a gas state having the low pressure P_L flows into the low-stage compressor 12. The low-stage compressor 12 sucks the refrigerant having the low pressure P_L and compresses the refrigerant to the intermediate pressure P_M (state of point F). The refrigerant in a gas state having the intermediate pressure P_M (state of point F) discharged from the low-stage compressor 12 is joined to the refrigerant in a two-phase state having the intermediate pressure P_M (state of point I) that flows out of the heat inter changer (HIC) 30 in the direction of arrow P2, and becomes the refrigerant having a quality of almost saturated vapor (state of point J). The refrigerant having this quality is sucked into the high-stage compressor 11, and the same cycle is repeated again.

[0043] In the refrigeration cycle apparatus according to Embodiment 1, a zeotropic refrigerant, for example, is used as the refrigerant. In addition, in the refrigeration cycle apparatus according to Embodiment 1, a CO_2 refrigerant mixture, such as R463A, can be used particularly among zeotropic refrigerants. The composition of R463A includes 36 mass% R32, 30 mass% R125, 14 mass% R134a, 14 mass% R1234yf, and 6 mass% R744 (CO_2).

[0044] As described above, in the refrigeration cycle apparatus having the receiver 72 provided in the injection circuit 70, when a zeotropic refrigerant is used, the gas density in the receiver 72 varies according to the intermediate pressure P_M. Consequently, the composition of the refrigerant flowing in the injection circuit 70 changes and, as a result, the composition of the circulating refrigerant circulating in the refrigerant pipe 60 changes. Especially when a CO_2 refrigerant mixture among zeotropic refrigerants is used, the magnitude of change in the composition of the circulating refrigerant is large. That is, because CO_2 (carbon dioxide) has an extremely different boiling temperature from those of other refrigerants, a CO_2 refrigerant mixture has a tendency to become a high-pressure refrigerant compared with other refrigerants. Because R463A contains only 6% of CO_2 of the total, when the proportion of CO_2 is slightly changed, this composition change exerts a great impact on the refrigeration capacity of the refrigeration cycle apparatus. On the other hand, with a refrigerant originally containing a large content of CO_2, even when the proportion of CO_2 is slightly changed, the composition change has little influence. When a zeotropic refrigerant that contains a small amount of CO_2, such as R463A, is used, leakage of a small amount of CO_2 from the circulating refrigerant has a big influence. Therefore, the change in the composition of the circulating refrigerant due to leakage of a small amount of CO_2 causes a significant impact on the refrigeration capacity of the refrigeration cycle apparatus. As a result, in the refrigeration cycle apparatus, insufficiency of the refrigeration capacity may occur in the evaporator 50, and there is a possibility that a decent cooling operation cannot be performed.

[0045] Therefore, in the refrigeration cycle apparatus according to Embodiment 1, insufficiency of cooling is avoided by controlling the intermediate pressure P_M, which is the internal pressure of the receiver 72, to stabilize the composition of the circulating refrigerant circulating in the refrigerant pipe 60. More specifically, the intermediate pressure P_M is controlled by using a control method (M1) or (M2) described below.

[0046] Control method (M1): control is exercised such that the intermediate pressure P_M falls to or below a first threshold. By reducing or eliminating an increase of the intermediate pressure P_M, variation in the gas density in the receiver 72 can be reduced, and thus the composition of the circulating refrigerant can be stabilized.

[0047] Control method (M2): control is exercised such that the intermediate pressure P_M is kept constant. As long as the intermediate pressure P_M is kept constant and stabilized, variation in the gas density in the receiver 72 can be reduced, and thus the composition of the circulating refrigerant can be stabilized.

[Regarding Control Method (M1)]

[0048] First, the control method (M1) will be described. Fig. 4 is a flowchart illustrating a flow of processing in the control method (M1). In Fig. 4, control is exercised such at the intermediate pressure P_M falls to or below a first threshold.

[0049] As shown in Fig. 4, in step S1, the controller 90 obtains a detection value of the intermediate pressure P_M from the pressure sensor 81.

[0050] Next, in step S2, the controller 90 compares the intermediate pressure P_M to the first threshold. When the comparison result indicates that the intermediate pressure P_M is greater than the first threshold, the process proceeds to step S3. Meanwhile, when the comparison result indicates that the intermediate pressure P_M is less than or equal to the first threshold, the processing of flow in Fig. 4 is terminated with no further processing.

[0051] In step S3, the controller 90 performs a predetermined first processing for the intermediate pressure P_M such that the intermediate pressure P_M falls to or below the first threshold. With this processing, the intermediate pressure P_M is lowered.

[0052] The first threshold is, for example, a geometric mean of the low pressure P_L and the high pressure P_H. In this case, the first threshold is calculated by the following formula (1).

$$\text{First threshold} = (P_L \times P_H)^{1/2} \qquad (1)$$

[0053] In the refrigeration cycle apparatus having the low-stage compressor 12 and the high-stage compressor 11, it is most preferable, in terms of performance, to exercise an equal pressure ratio control in which the pressure ratios of the low-stage compressor 12 and the high-stage compressor 11 are made equal. Thus, in this case, the first threshold for the intermediate pressure P_M, which is the discharge pressure of the low-stage compressor 12, is set to a geometric means of the low pressure P_L, which is the pressure of the refrigerant sucked by the low-stage compressor 12, and the high pressure P_H, which is the pressure of the refrigerant discharged by the high-stage compressor 11.

[0054] Examples of the first processing include processing (a1) and processing (b1) described below. The controller 90 is configured to perform at least one of the processing (a1) and processing (b1) as the "first processing".

[Processing (a1): Control by Displacement]

[0055] The first processing in a case of the processing (a1) will be described. In the first processing in the case of the processing (a1), the controller 90 is configured to increase a ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12. That is, the controller 90 increases the ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12. In this case, the displacement of the low-stage compressor 12 and the displacement of the high-stage compressor 11 are calculated by the following formula (2). That is, not only the rotating speed ratio of the low-stage compressor 12 and the high-stage compressor 11 but also the volume ratio of the low-stage compressor 12 and the high-stage compressor 11 is taken into account.

$$\text{Displacement of low-stage compressor} = \text{volume of low-stage compressor} \times \text{rotating speed of low-stage compressor}$$

$$\text{Displacement of high-stage compressor} = \text{volume of high-stage compressor} \times \text{rotating speed of high-stage compressor} \qquad (2)$$

[0056] Although the controller 90 can increase the ratio of displacement by a predetermined fixed amount, the controller 90 may increase the ratio of displacement by an amount corresponding to the value of the intermediate pressure P_M. In this case, the storage circuitry of the controller 90 stores in advance a data table in which values of the intermediate pressure P_M and increased amounts of ratio of displacement are stored in association with each other. In addition, because the ratio of the volume of the low-stage compressor 12 and the volume of the high-stage compressor 11 is constant, the controller 90 actually increases a ratio of rotating speed of the high-stage compressor 11 to rotating speed of the low-stage compressor 12. Thus, more specifically, the controller 90 controls at least one of the rotating speed of the low-stage compressor 12 and the rotating speed of the high-stage compressor 11.

[Processing (b1): Control by Opening Degree of INJ Expansion Valve 71]

[0057] The first processing in a case of the processing (b1) will be described. In the first processing in the case of the processing (b1), the controller 90 is configured to reduce the opening degree of the INJ expansion valve 71.

[0058] Although the controller 90 can reduce the opening degree of the INJ expansion valve 71 by a predetermined fixed amount, the controller 90 may reduce the opening degree of the INJ expansion valve 71 by an amount corresponding to the value of the intermediate pressure P_M. In this case, the storage circuitry of the controller 90 stores in advance a data table in which values of the intermediate pressure P_M and reduced amounts of opening degree of the INJ expansion valve 71 are stored in association with each other.

[0059] As described above, the controller 90 performs the predetermined first processing in step S3. With this processing, the intermediate pressure P_M is lowered. The controller 90 is configured to perform the processing of the flow of Fig. 4 repeatedly at fixed intervals. Thus, the intermediate pressure P_M can be controlled to fall to or below the first threshold. By controlling the intermediate pressure P_M such that the intermediate pressure P_M is constantly kept at or below the first threshold in this way, the refrigerant composition of the circulating refrigerant is stabilized, and thus insufficiency of cooling can be avoided.

[Regarding Control Method (M2)]

[0060] Next, the control method (M2) above will be described. Fig. 5 is a flowchart illustrating a flow of processing in the control method (M2). In Fig. 5, the controller 90 is configured to exercise control to keep the intermediate pressure P_M constant (that is, at a constant value). However, in an actual operation, there is a possibility that the intermediate pressure P_M slightly fluctuates around the constant value. For this reason, the constant value is set to have a certain range. That is, a description is made for a case where the intermediate pressure P_M is controlled such that the intermediate pressure P_M is kept within a first range including the constant value. Here, the "constant" is defined as a state of being constant within a predetermined first range, or a state of being substantially constant with slight fluctuation. Note that, the first range is described as a range that is greater than a predetermined second threshold and less than or equal to the first threshold.

[0061] In Fig. 5, processing of step S4 and processing of step S5 are added to the flow of Fig. 4.

[0062] In step S1, the controller 90 obtains a detection value of the intermediate pressure P_M from the pressure sensor 81.

[0063] Next, in step S2, the controller 90 compares the intermediate pressure P_M to the first threshold. When the comparison result indicates that the intermediate pressure P_M is greater than the first threshold, the process proceeds to step S3. Meanwhile, when the comparison result indicates that the intermediate pressure P_M is less than or equal to the first threshold, the process proceeds to step S4.

[0064] In step S3, the controller 90 performs the predetermined first processing for the intermediate pressure P_M such that the intermediate pressure P_M falls to or below the first threshold. With this processing, the intermediate pressure P_M is lowered. Because the first processing is described above, its description is omitted here.

[0065] In step S4, the controller 90 compares the intermediate pressure P_M to the second threshold. When the comparison result indicates that the intermediate pressure P_M is greater than the second threshold, the processing of flow in Fig. 5 is terminated with no further processing. Meanwhile, when the comparison result indicates that the intermediate pressure P_M is less than or equal to the second threshold, the process proceeds to step S5.

[0066] In step S5, the controller 90 performs the predetermined second processing for the intermediate pressure P_M such that the intermediate pressure P_M becomes higher than the second threshold. Thus, the intermediate pressure P_M is raised.

[0067] The second threshold is, for example, a value in which a negative tolerance α is provided to the first threshold. That is, the second threshold is smaller than the first threshold by a value of α. Here, α is a predetermined positive real number. In this case, the second threshold is calculated by the following formula (3). Note that, as the value of α decreases, a fluctuation range of the intermediate pressure P_M decreases. Therefore, the value of α is determined, as appropriate, on the basis of an allowable fluctuation range for the intermediate pressure P_M to be controlled constant.

$$\text{Second threshold} = \text{first threshold} - \alpha \qquad (3)$$

[0068] Examples of the second processing include processing (a2) and processing (b2) described below. The controller 90 is configured to perform at least one of the processing (a2) and processing (b2) as the "second processing".

[Processing (a2): Control by Displacement]

[0069] The second processing in a case of the processing (a2) will be described. In the second processing in the case of the processing (a2), the controller 90 is configured to reduce a ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12. That is, the controller 90 reduces the ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12. In this case, the displacement of the low-stage compressor 12 and the displacement of the high-stage compressor 11 are calculated by the formula (2) described above.

[0070] Although the controller 90 can reduce the ratio of displacement by a predetermined fixed amount, the controller 90 may reduce the ratio of displacement by an amount corresponding to the value of the intermediate pressure P_M. In this case, the storage circuitry of the controller 90 stores in advance a data table in which values of the intermediate pressure P_M and reduced amounts of ratio of displacement are stored in association with each other. In addition, given that the volume of the low-stage compressor 12 and the volume of the high-stage compressor 11 are constant, a ratio of rotating speed of the high-stage compressor 11 to rotating speed of the low-stage compressor 12 is reduced. More specifically, the controller 90 controls at least one of the rotating speed of the low-stage compressor 12 and the rotating speed of the high-stage compressor 11.

[Processing (b2): Control by Opening Degree of INJ Expansion Valve 71]

[0071] The second processing in a case of the processing (b2) will be described. In the second processing in the case of the processing (b2), the controller 90 is configured to increase the opening degree of the INJ expansion valve 71.

[0072] Although the controller 90 can increase the opening degree of the INJ expansion valve 71 by a predetermined fixed amount, the controller 90 may increase the opening degree of the INJ expansion valve 71 by an amount corresponding to the value of the intermediate pressure P_M. In this case, the storage circuitry of the controller 90 stores in advance a data table in which values of the intermediate pressure P_M and increased amounts of opening degree of the INJ expansion valve 71 are stored in association with each other.

[0073] As described above, the controller 90 performs the predetermined second processing in step S5. With this processing, the intermediate pressure P_M is raised. The controller 90 is configured to perform the processing of the flow of Fig. 5 repeatedly at fixed intervals. Thus, the intermediate pressure P_M can be controlled such that the intermediate pressure P_M is kept constant or substantially constant within the first range. That is, the intermediate pressure P_M can be controlled such that a relationship of first threshold $\geq$ intermediate pressure P_M > second threshold is constantly satisfied. By controlling the intermediate pressure P_M such that the intermediate pressure P_M is constantly kept constant within the first range in this way, the gas density in the receiver 72 is stabilized, the refrigerant composition of the circulating refrigerant is stabilized, and thus insufficiency of cooling can be avoided.

[0074] Fig. 6 is a flowchart illustrating a flow of processing when processing (a1) and processing (a2) are performed as the first processing and the second processing in the flow of Fig. 5. In Fig. 6, the controller 90 controls the intermediate pressure P_M by controlling the ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12.

[0075] In Fig. 6, the processing of step S13 is performed in place of step S3 of Fig. 5. In step S13, the controller 90 increases the ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12. As a result, the intermediate pressure P_M is lowered.

[0076] In addition, in Fig. 6, the processing of step S15 is performed in place of step S5 of Fig. 5. In step S15, the controller 90 reduces the ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12. As a result, the intermediate pressure P_M is raised.

[0077] The other steps such as S1, S2, and S4 in Fig. 6 are the same as those of Fig. 5, and thus their descriptions are omitted here.

[0078] Fig. 7 is a flowchart illustrating a flow of processing when processing (b1) and processing (b2) are performed as the first processing and the second processing in the flow of Fig. 5. In Fig. 7, the controller 90 controls the intermediate pressure P_M by controlling the opening degree of the INJ expansion valve 71.

[0079] In Fig. 7, the processing of step S23 is performed in place of step S3 of Fig. 5. In step S23, the controller 90 reduces the opening degree of the INJ expansion valve 71. As a result, the intermediate pressure P_M is lowered.

[0080] In addition, in Fig. 7, the processing of step S25 is performed in place of step S5 of Fig. 5. In step S25, the controller 90 increases the opening degree of the INJ expansion valve 71. As a result, the intermediate pressure P_M is raised.

[0081] The other steps such as S1, S2, and S4 in Fig. 7 are the same as those of Fig. 5, and thus their descriptions are omitted here.

[0082] Fig. 8 is a refrigerant circuit diagram illustrating the configuration of a modified example of the refrigeration cycle apparatus according to Embodiment 1. Fig. 8 differs from Fig. 1 in that the compressor 10 in Fig. 8 is formed by an injection compressor 13. As shown in Fig .8, the compressor 10 may be formed by the injection compressor 13, which is a single-stage compressor provided with an intermediate pressure INJ port. In this case, the intermediate pressure P_M is controlled by controlling the opening degree of the INJ expansion valve 71 by using the control method (M2) described above. Because the other configurations and operations are the same as those of Fig. 1, the other configurations and operations are denoted by the same reference signs, and their descriptions are omitted here.

[0083] Fig. 9 is an explanatory diagram schematically illustrating the configuration of the low-stage compressor 12 and the high-stage compressor of Fig. 1. Fig. 10 is an explanatory diagram schematically illustrating the configuration of the injection compressor 13 of Fig. 8. Fig. 9 shows the configuration of a general rotary compressor. The high-stage compressor 11 and the low-stage compressor 12 of Fig. 1 each have the configuration shown in Fig. 9. In Fig. 9, the compressor has a suction port 10a from which refrigerant is sucked and a discharge port 10b from which refrigerant is discharged. In addition, a compression mechanism 10c, which compresses refrigerant, and a driving mechanism 10d, which drives the compression mechanism 10c, are provided in the compressor. The compression mechanism 10c has a compression chamber 10c-1 in which refrigerant is compressed. The driving mechanism 10d is formed by, for example, a driving motor that drives the compression mechanism 10c. In addition, an accumulator 10e may be provided on the suction port 10a side.

[0084] Fig. 10 shows the configuration of an injection rotary compressor forming the injection compressor 13. As shown in Fig. 10, in the injection compressor 13, an intermediate pressure INJ port 10f, which is an injection refrigerant suction port, is added to the configuration of Fig. 9. The refrigerant having the intermediate pressure Pnn flowing in the injection circuit 70 is sucked into the intermediate pressure INJ port 10f. The refrigerant is caused to flow into the compression chamber 10c-1 provided in the compression mechanism 10c. The refrigerant having the low pressure P_L flowing from the evaporator 50 is sucked into the suction port 10a of the injection compressor 13. In the compression chamber 10c-1 of the injection compressor 13, the refrigerant that flows out of the evaporator 50 and the refrigerant that flows in from the injection circuit 70 are mixed and compressed to the high pressure P_H.

[0085] Furthermore, an injection pipe 10h connected to the intermediate pressure INJ port 10f may be provided with an injection muffler 10g. The injection muffler 10g is configured to prevent the refrigerant from flowing backward from the compression chamber 10c-1 to the intermediate pressure INJ port 10f. In addition, by installing mesh inside the injection muffler 10g, a foreign object can be captured by the mesh, and thus reliability can be further enhanced.

[0086] Although, in Fig. 9 and Fig. 10, a case where a rotary compressor is used is described, the compressor is not limited to this case. The low-stage compressor 12 and the high-stage compressor 11 each may be formed by a scroll compressor or a screw compressor. In addition, the injection compressor 13 may be formed by a scroll compressor, or a screw compressor, provided with the intermediate pressure INJ port 10f.

[0087] Because the operations of the refrigeration cycle apparatus in the case of Fig. 8 are basically the same as those of the refrigeration cycle apparatus of Fig. 1, their descriptions are omitted here.

[0088] As described above, in Embodiment 1, the compressor 10 may be formed by the high-stage compressor 11 and the low-stage compressor 12 as shown in Fig. 1, or may be formed by the injection compressor 13 as shown in Fig. 8. In either case, the same effect can be obtained.

[0089] As described above, the refrigeration cycle apparatus according to Embodiment 1 includes the injection circuit

70 having the INJ expansion valve 71 and the receiver 72. Furthermore, the controller 90 is configured to control at least one of the operation of the compressor 10 and the opening degree of the INJ expansion valve 71 such that the intermediate pressure P_M, which is the internal pressure of the receiver 72, falls to or below the first threshold. Alternatively, the controller 90 is configured to control the intermediate pressure P_M to fall within the first range. With this control, the gas density of the refrigerant staying in the receiver 72 is reduced, and thus change in the composition of the circulating refrigerant from the original composition is reduced. As a result, the composition of the circulating refrigerant is stabilized, and therefore change from the original composition can be minimized as possible. When the composition of the circulating refrigerant is stabilized, variation in the refrigeration capacity of the refrigeration cycle apparatus is reduced or eliminated, and insufficient cooling of an indoor space by the evaporator 50 can be prevented.

[0090] Furthermore, in Embodiment 1, when the intermediate pressure P_M is controlled by operation of the compressor, the control is exercised by controlling the ratio of displacement of the high-stage compressor 11 to displacement of the low-stage compressor 12. When the control is exercised by controlling the ratio of rotating speed of the high-stage compressor 11 to rotating speed of the low-stage compressor 12, instead of the ratio of displacement, the volume ratio of the low-stage compressor 12 and the high-stage compressor 11 is not taken into account. On the other hand, in Embodiment 1, because the control is exercised by using the ratio of displacement, the rotating speed ratio is controlled while the volume ratio of the low-stage compressor 12 and the high-stage compressor 11 is taken into account. Therefore, the intermediate pressure P_M can be controlled with higher accuracy in Embodiment 1.

[0091] Moreover, because a CO_2 refrigerant mixture, in particular, causes a significant composition change, the refrigeration cycle apparatus according to Embodiment 1 is especially effective when a CO_2 refrigerant mixture is used.

[0092] In addition, because the refrigeration cycle apparatus according to Embodiment 1 is provided with the heat inter changer (HIC) 30, subcooling can be increased, and the performance of the refrigeration cycle apparatus can be further improved.

Reference Signs List

[0093] 10: compressor, 10a: suction port, 10b: discharge port, 10c: compression mechanism, 10c-1: compression chamber, 10d: driving mechanism, 10e: accumulator, 10f: intermediate pressure INJ port, 10g: injection muffler, 11: high-stage compressor, 12: low-stage compressor, 13: injection compressor, 20: condenser, 31: outer pipe, 32: inner pipe, 40: expansion valve, 50: evaporator, 60: refrigerant pipe, 61: INJ branch unit, 62: INJ junction unit, 70: injection circuit, 71: INJ expansion valve, 72: receiver, 73: flow control valve, 74: gas vent pipe, 75: on-off valve, 76: injection pipe, 81: pressure sensor, 90: controller, P1: arrow, P2: arrow, P_H: high pressure (second pressure), P_L: low pressure (first pressure), P_M: intermediate pressure

Claims

1. A refrigeration cycle apparatus comprising:

a controller;
a compressor configured to compress refrigerant to cause a pressure of the refrigerant to rise from a first pressure to a second pressure higher than the first pressure;
a condenser configured to cause heat exchange to be performed between air and the refrigerant discharged from the compressor;
an INJ branch unit configured to cause the refrigerant that flows out of the condenser to branch into first refrigerant and second refrigerant;
an expansion valve configured to expand the first refrigerant that flows out of the INJ branch unit to reduce a pressure of the first refrigerant to the first pressure;
an evaporator configured to cause heat exchange to be performed between air and the first refrigerant that flows out of the expansion valve, and cause the first refrigerant having the first pressure to flow to the compressor; and
an injection circuit connected between the INJ branch unit and the compressor, and configured to cause the second refrigerant that flows out of the INJ branch unit to flow to the compressor,
wherein the injection circuit includes
an INJ expansion valve configured to expand the second refrigerant to reduce a pressure of the second refrigerant to an intermediate pressure that is higher than the first pressure and lower than the second pressure, and
a receiver configured to store the second refrigerant that flows out of the INJ expansion valve, and cause the second refrigerant having the intermediate pressure to flow to the compressor, and
wherein the controller is configured to control at least one of a rotating speed of the compressor and an opening

degree of the INJ expansion valve such that the intermediate pressure falls to or below a first threshold or is kept constant within a first range, the intermediate pressure corresponding to an internal pressure of the receiver.

2. The refrigeration cycle apparatus of claim 1, further comprising

a pressure sensor provided between the INJ expansion valve and the receiver, and configured to detect the intermediate pressure corresponding to the internal pressure of the receiver,
wherein the controller is configured to control the intermediate pressure corresponding to the internal pressure of the receiver based on the intermediate pressure detected by the pressure sensor such that the intermediate pressure falls to or below the first threshold or is kept constant within the first range.

3. The refrigeration cycle apparatus of claim 1 or 2, wherein the controller is configured to, when the intermediate pressure corresponding to the internal pressure of the receiver is higher than the first threshold, reduce the opening degree of the INJ expansion valve to reduce the intermediate pressure.

4. The refrigeration cycle apparatus of claim 3, wherein the controller is configured to, when the intermediate pressure corresponding to the internal pressure of the receiver is lower than or equal to a second threshold that is smaller than the first threshold, increase the opening degree of the INJ expansion valve to raise the intermediate pressure.

5. The refrigeration cycle apparatus of any one of claims 1 to 4,

wherein the compressor is formed by a single-stage compressor having an intermediate pressure INJ port, and
wherein one end of the injection circuit is connected to the INJ branch unit, and an other end of the injection circuit is connected to the intermediate pressure INJ port of the compressor.

6. The refrigeration cycle apparatus of any one of claims 1 to 4,

wherein the compressor includes
a low-stage compressor provided between the evaporator and an INJ junction unit, and configured to compress the first refrigerant having the first pressure that flows out of the evaporator to cause the pressure of the first refrigerant to rise from the first pressure to the intermediate pressure, and
a high-stage compressor provided between the INJ junction unit and the condenser, and configured to suck refrigerant joined at the INJ junction unit and compress the sucked refrigerant to cause a pressure of the refrigerant to rise to the second pressure, and
wherein the INJ junction unit is provided between a discharge side of the low-stage compressor and a suction side of the high-stage compressor, and is configured to join the first refrigerant discharged from the low-stage compressor and the second refrigerant that flows out of the injection circuit, and
wherein one end of the injection circuit is connected to the INJ branch unit, and an other end of the injection circuit is connected to the INJ junction unit.

7. The refrigeration cycle apparatus of claim 6,

wherein the controller is configured to control a ratio of displacement of the high-stage compressor to displacement of the low-stage compressor such that the intermediate pressure corresponding to the internal pressure of the receiver falls to or below the first threshold or is kept constant within the first range,
wherein the displacement of the low-stage compressor is a value obtained by multiplying a volume of the low-stage compressor and a rotating speed of the low-stage compressor, and
wherein the displacement of the high-stage compressor is a value obtained by multiplying a volume of the high-stage compressor and a rotating speed of the high-stage compressor.

8. The refrigeration cycle apparatus of claim 7, wherein the controller is configured to, when the intermediate pressure corresponding to the internal pressure of the receiver is higher than the first threshold, increase the ratio of the displacement of the high-stage compressor to the displacement of the low-stage compressor to reduce the intermediate pressure.

9. The refrigeration cycle apparatus of claim 8, wherein the controller is configured to, when the intermediate pressure corresponding to the internal pressure of the receiver is lower than or equal to a second threshold that is smaller than the first threshold, reduce the ratio of the displacement of the high-stage compressor to the displacement of the low-stage compressor to raise the intermediate pressure.

10. The refrigeration cycle apparatus of any one of claims 1 to 9, wherein the first threshold is a geometric mean of the first pressure and the second pressure.

11. The refrigeration cycle apparatus of any one of claims 1 to 10,

wherein the first range is a range less than or equal to the first threshold and greater than a second threshold, and
wherein the second threshold is smaller than the first threshold.

12. The refrigeration cycle apparatus of any one of claims 1 to 11, further comprising

a heat inter changer provided between the condenser and the INJ branch unit, and configured to apply subcooling to the refrigerant that flows out of the condenser,
wherein the INJ branch unit is configured to cause the refrigerant that flows out of the heat inter changer to branch into the first refrigerant and the second refrigerant, and
wherein the receiver is configured to cause the second refrigerant having the intermediate pressure staying in the receiver to flow to the compressor via the heat inter changer.

FIG. 1

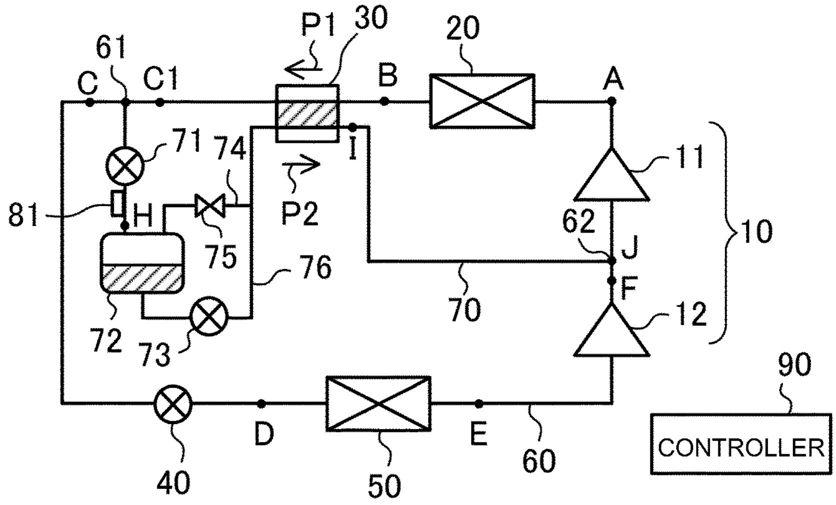

P1
30
20
61
C
C1
B
A
71
74
I
11
81
H
P2
62
J
10
75
76
F
70
12
72
73
90
40
D
E
60
50
CONTROLLER

FIG. 2

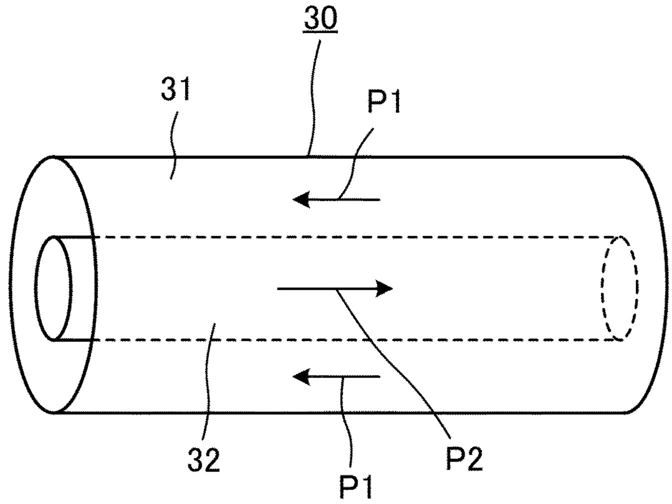

30
31
P1
32
P1
P2

FIG. 3

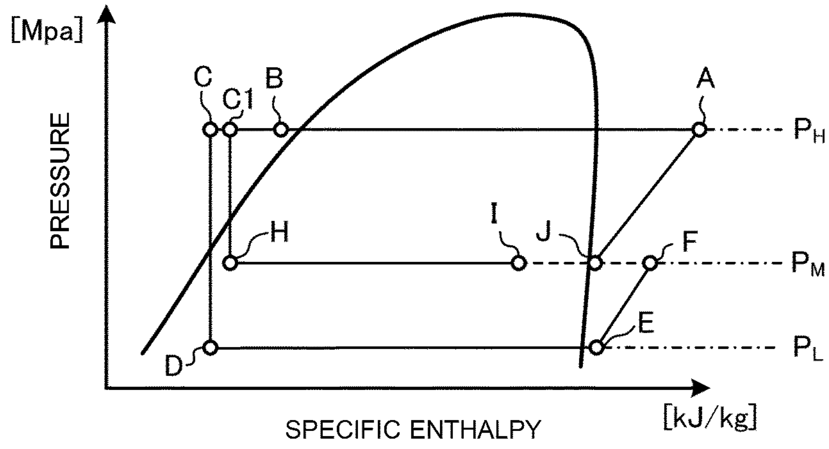

[Mpa]
PRESSURE
C
C1
B
A
P_H
H
I
J
F
P_M
E
D
P_L
SPECIFIC ENTHALPY
[kJ/kg]

FIG. 4

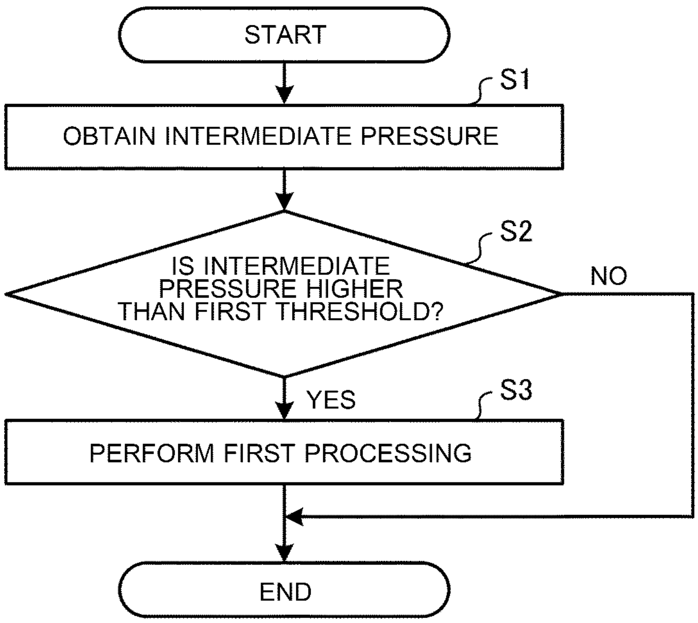

START
S1
OBTAIN INTERMEDIATE PRESSURE
S2
IS INTERMEDIATE PRESSURE HIGHER THAN FIRST THRESHOLD?
NO
YES
S3
PERFORM FIRST PROCESSING
END

FIG. 5

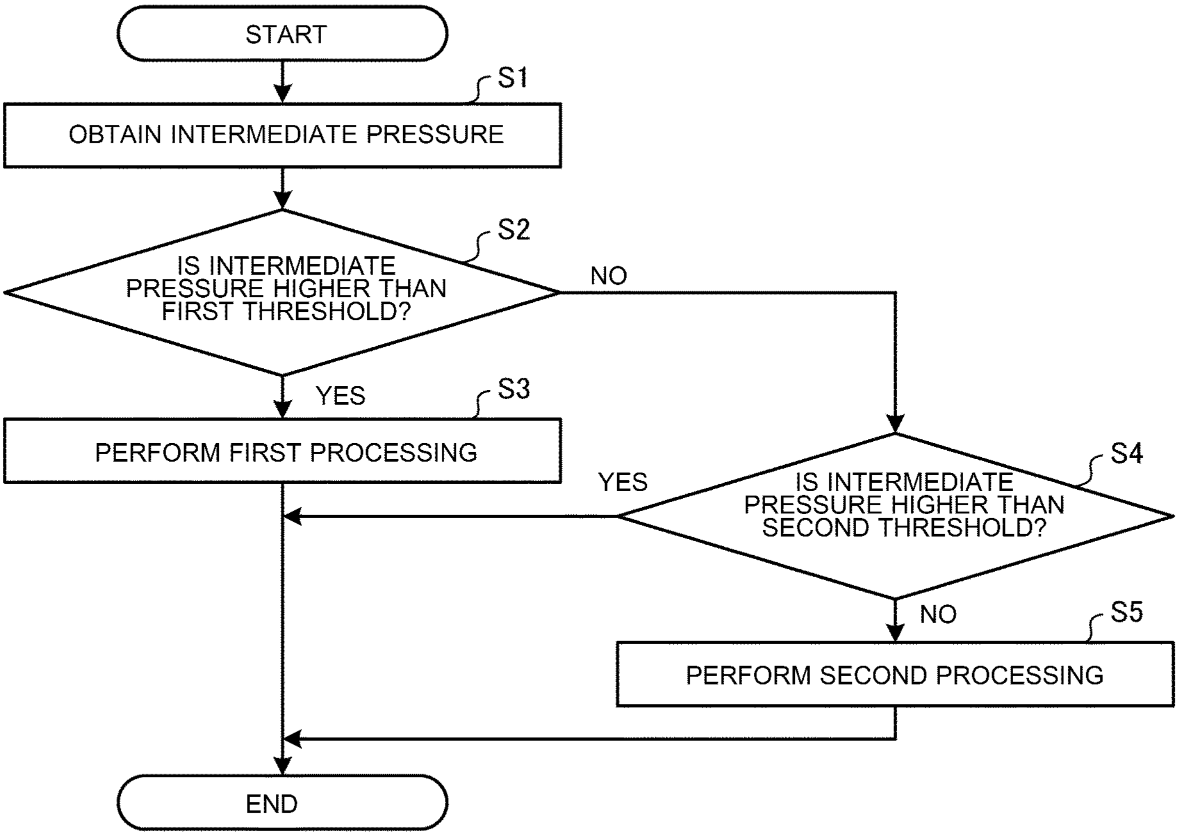

START
S1
OBTAIN INTERMEDIATE PRESSURE
S2
IS INTERMEDIATE PRESSURE HIGHER THAN FIRST THRESHOLD?
NO
YES
S3
PERFORM FIRST PROCESSING
YES
S4
IS INTERMEDIATE PRESSURE HIGHER THAN SECOND THRESHOLD?
NO
S5
PERFORM SECOND PROCESSING
END

FIG. 6

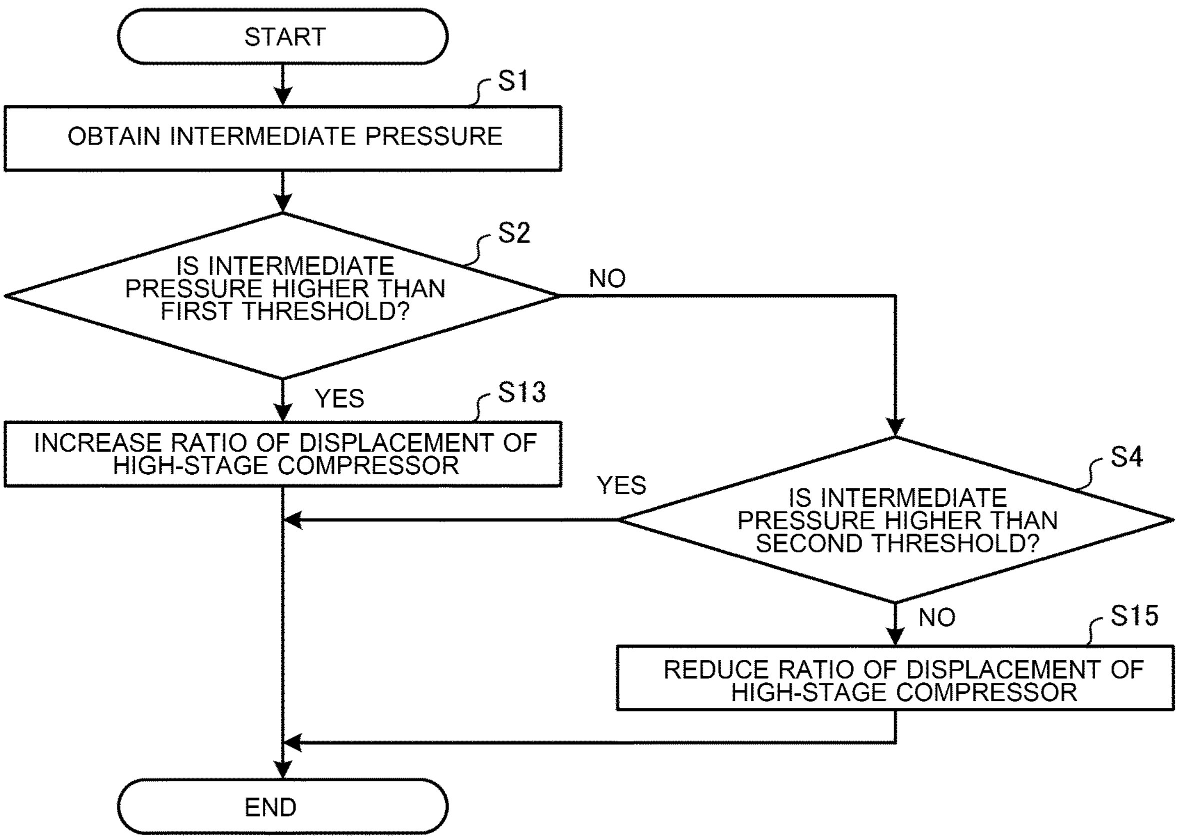

START
S1
OBTAIN INTERMEDIATE PRESSURE
S2
IS INTERMEDIATE PRESSURE HIGHER THAN FIRST THRESHOLD?
NO
YES
S13
INCREASE RATIO OF DISPLACEMENT OF HIGH-STAGE COMPRESSOR
YES
S4
IS INTERMEDIATE PRESSURE HIGHER THAN SECOND THRESHOLD?
NO
S15
REDUCE RATIO OF DISPLACEMENT OF HIGH-STAGE COMPRESSOR
END

FIG. 7

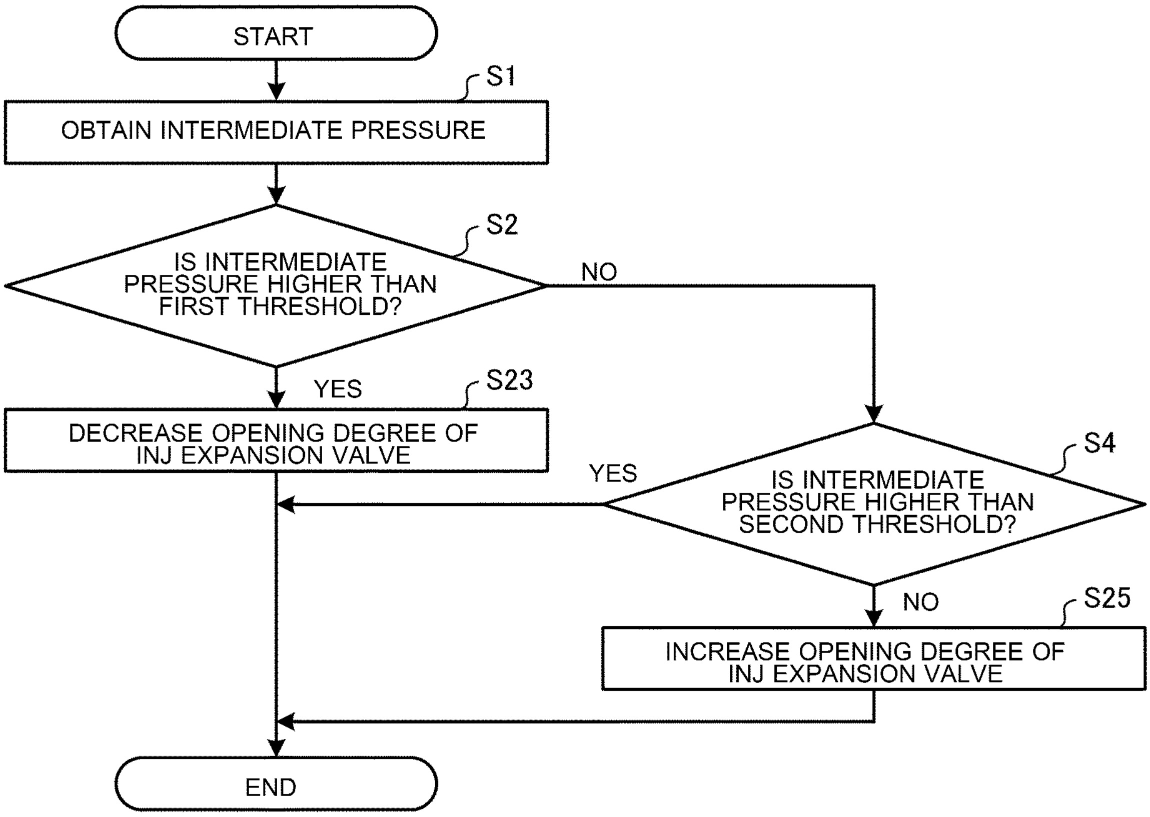

START
S1
OBTAIN INTERMEDIATE PRESSURE
S2
IS INTERMEDIATE PRESSURE HIGHER THAN FIRST THRESHOLD?
NO
YES
S23
DECREASE OPENING DEGREE OF INJ EXPANSION VALVE
S4
YES
IS INTERMEDIATE PRESSURE HIGHER THAN SECOND THRESHOLD?
NO
S25
INCREASE OPENING DEGREE OF INJ EXPANSION VALVE
END

FIG. 8

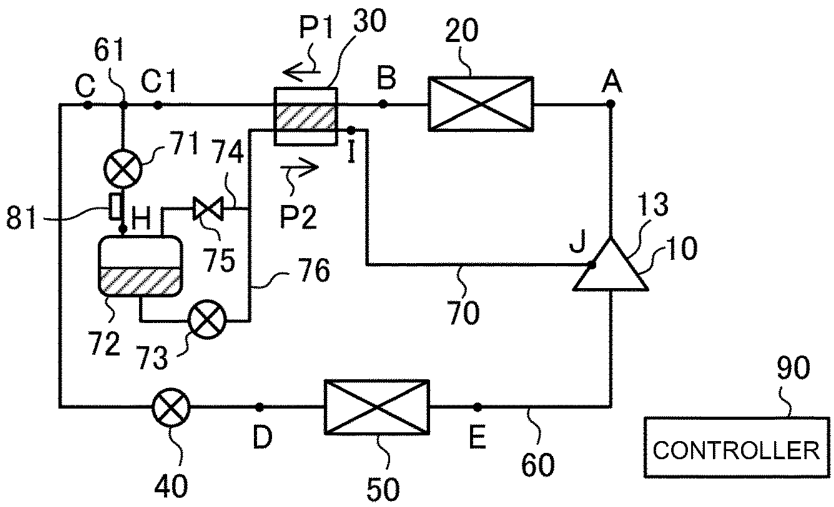

P1
30
20
61
C1
B
A
C
71
74
I
P2
81
H
75
13
J
10
76
70
72
73
90
40
D
50
E
60
CONTROLLER

FIG. 9

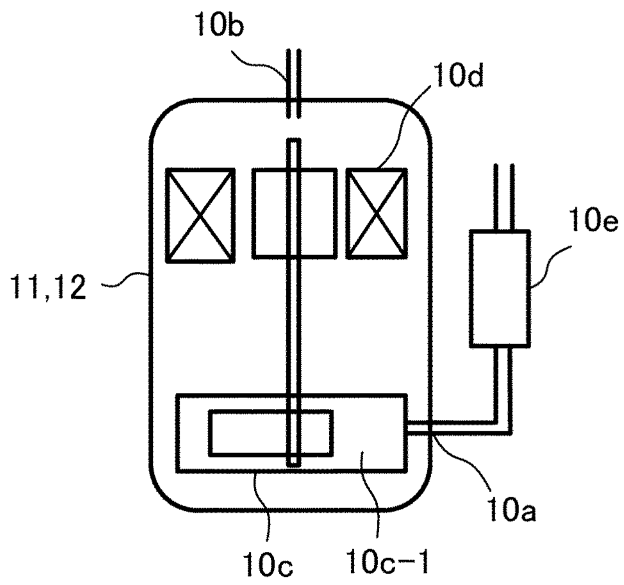
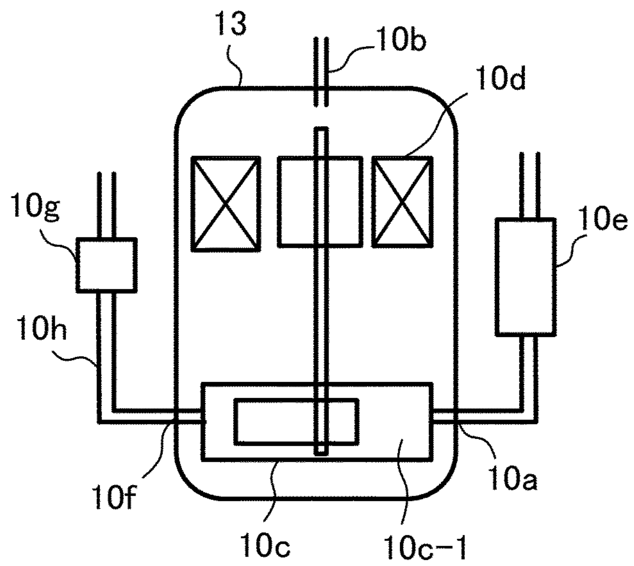

10b
10d
10e
11,12
10a
10c
10c-1

FIG. 10


13
10b
10d
10g
10e
10h
10f
10a
10c
10c-1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/019830

A. CLASSIFICATION OF SUBJECT MATTER

F25B 1/00(2006.01)i; ***F25B 1/10***(2006.01)i
FI: F25B1/00 311D; F25B1/10 E

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)

F25B1/00; F25B1/10

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2021
Registered utility model specifications of Japan 1996-2021
Published registered utility model applications of Japan 1994-2021

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 A	WO 2021/048899 A1 (MITSUBISHI ELECTRIC CORP.) 18 March 2021 (2021-03-18) paragraphs [0012]-[0067], fig. 1-6	1-6, 10-12 7-9
Y A	JP 2018-36016 A (DAIKIN INDUSTRIES, LTD.) 08 March 2018 (2018-03-08) paragraphs [0032]-[0135], fig. 1-3	1-6, 10-12 7-9
Y A	JP 2018-9767 A (DAIKIN INDUSTRIES, LTD.) 18 January 2018 (2018-01-18) paragraphs [0035]-[0135], fig. 1-3	1-6, 10-12 7-9
Y	WO 2020/208752 A1 (MITSUBISHI ELECTRIC CORP.) 15 October 2020 (2020-10-15) fig. 1	12
A	JP 2018-132223 A (PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO., LTD.) 23 August 2018 (2018-08-23) entire text, all drawings	7-9

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
22 June 2021	**06 July 2021**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	 Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/019830

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2012-88040 A (DAIKIN INDUSTRIES, LTD.) 10 May 2012 (2012-05-10) entire text, all drawings	7-9

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/019830

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO 2021/048899 A1	18 March 2021	(Family: none)	
JP 2018-36016 A	08 March 2018	(Family: none)	
JP 2018-9767 A	18 January 2018	(Family: none)	
WO 2020/208752 A1	15 October 2020	(Family: none)	
JP 2018-132223 A	23 August 2018	(Family: none)	
JP 2012-88040 A	10 May 2012	US 2011/0179822 A1 entire text, all drawings WO 2010/038360 A1 EP 2336675 A1 CN 102159906 A JP 2010-107178 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- JP 2018021732 A **[0007]**