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

(11) EP 3 246 637 A1

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

(43) Date of publication:
22.11.2017 Bulletin 2017/47

(21) Application number: **15877851.4**

(22) Date of filing: **16.01.2015**

(51) Int Cl.:
F25B 1/00 *(2006.01)*

(86) International application number:
PCT/JP2015/051068

(87) International publication number:
WO 2016/113899 (21.07.2016 Gazette 2016/29)

(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

(71) Applicant: **Mitsubishi Electric Corporation**
Chiyoda-ku
Tokyo 100-8310 (JP)

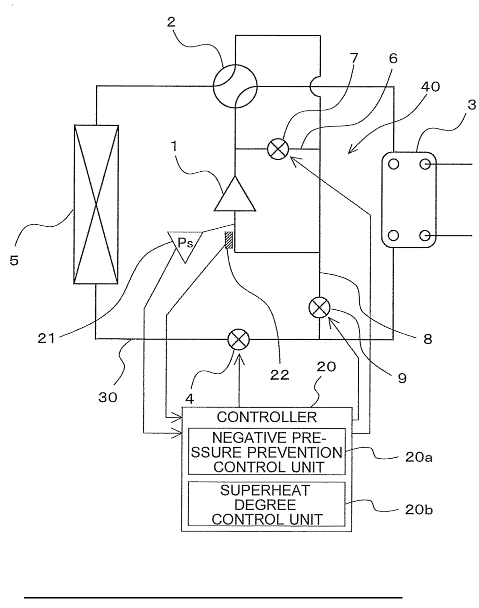
(72) Inventors:
- **SAIKUSA, Tetsuji**
  Tokyo 102-0073 (JP)
- **KADOWAKI, Kimitaka**
  Tokyo 102-0073 (JP)
- **OBAYASHI, Tomoyoshi**
  Tokyo 102-0073 (JP)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(54) REFRIGERATION CYCLE DEVICE

(57) There are included: a main circuit 30 in which a compressor 1, a condenser 3, a main expansion valve 4, and an evaporator 5 are connected in a circle, and through which refrigerant having a higher boiling point than R407C circulates; a bypass 40 (a discharged gas bypass 6 and a suction bypass 8) configured to combine a flow of part of refrigerant discharged from the compressor 1 and a flow of refrigerant having flowed out of the condenser 3 into a combined flow to allow the combined flow to flow into a suction side of the compressor 1; a negative pressure regulating valve (a discharged gas bypass valve 7) configured to regulate a flow rate in the bypass 40; and a negative pressure prevention control unit 20a configured to perform a negative pressure prevention operation of controlling the negative pressure regulating valve 7 to prevent a suction pressure of the compressor 1 from becoming negative.

FIG. 4



Printed by Jouve, 75001 PARIS (FR)

Description

Technical Field

[0001] The present invention relates to a refrigeration cycle apparatus for a heat pump water heater or other apparatuses.

Background Art

[0002] As an existing refrigeration cycle apparatus, for example, an apparatus has been proposed in which "HFO-1234yf is used as refrigerant, at least a compressor, a condenser, an expansion device, and an evaporator are sequentially connected to form a circular refrigerant circuit, a four-way valve is provided to switch between directions in which the refrigerant flows, an indoor heat exchanger and an outdoor heat exchanger are respectively caused to work as an evaporator and a condenser in a cooling operation, and the indoor heat exchanger and the outdoor heat exchanger are respectively caused to work as a condenser and an evaporator in a heating operation" (see Patent Literature 1, for example).

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2011-252638

Summary of Invention

Technical Problem

[0004] HFO-1234yf used in the technique disclosed in Patent Literature 1 is refrigerant having a higher boiling point than refrigerant, such as R407C and R410A, having been used. For this reason, the refrigerant has the property that a compressor suction pressure decreases. Thus, when a heating operation is performed under low outdoor air temperature conditions in particular, the operation is performed in a negative pressure state in which a compressor suction pressure is lower than an atmospheric pressure, thereby causing the problem of the occurrence of a disadvantage, such as a malfunction due to suction of air.

[0005] The present invention has been made to solve a problem like that described above and provides a refrigeration cycle apparatus that, even when refrigerant having a higher boiling point than R407C refrigerant is used, can prevent a compressor suction pressure from falling to or below an atmospheric pressure under low outdoor air temperature conditions and increase reliability.

Solution to Problem

[0006] A refrigeration cycle apparatus according to one embodiment of the present invention includes: a main circuit in which a compressor, a condenser, a main expansion valve, and an evaporator are connected in a circle, and through which refrigerant having a higher boiling point than R407C circulates; a bypass configured to combine a flow of part of refrigerant discharged from the compressor and a flow of refrigerant having flowed out of the condenser into a combined flow to allow the combined flow to flow into a suction side of the compressor; a negative pressure regulating valve configured to regulate a flow rate in the bypass; and a negative pressure prevention control unit configured to perform a negative pressure prevention operation of controlling the negative pressure regulating valve to prevent a suction pressure of the compressor from becoming negative.

Advantageous Effects of Invention

[0007] According to one embodiment of the present invention, a refrigeration cycle apparatus can be obtained that, even when refrigerant having a higher boiling point than R407C refrigerant is used, can prevent a compressor suction pressure from falling to or below an atmospheric pressure under low outdoor air temperature conditions and increase reliability.

Brief Description of Drawings

[0008]

[Fig. 1] Fig. 1 is a refrigerant circuit diagram of a refrigeration cycle apparatus according to Embodiment 1 of the present invention.
[Fig. 2] Fig. 2 is a graph illustrating comparisons of relationships between saturation temperatures and saturated vapor pressures of various types of refrigerant.
[Fig. 3] Fig. 3 is a P-h diagram illustrating an action state in a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 1 of the present invention.
[Fig. 4] Fig. 4 is a system configuration diagram of the refrigeration cycle apparatus according to Embodiment 1 of the present invention.
[Fig. 5] Fig. 5 is a flowchart illustrating a control procedure of a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 1 of the present invention.
[Fig. 6] Fig. 6 is a system configuration diagram of the refrigeration cycle apparatus according to Embodiment 2 of the present invention.
[Fig. 7] Fig. 7 is a flowchart illustrating a control procedure of a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 2 of the present invention.
[Fig. 8] Fig. 8 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 3 of the present invention.
[Fig. 9] Fig. 9 is a schematic view of an ejector of Fig. 8.
[Fig. 10] Fig. 10 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 4 of the present invention.
[Fig. 11] Fig. 11 is a refrigerant circuit diagram of a refrigeration cycle apparatus illustrating Modification 1 of the refrigeration cycle apparatus according to Embodiment 4 of the present invention.
[Fig. 12] Fig. 12 is a refrigerant circuit diagram of a refrigeration cycle apparatus illustrating Modification 2 of the refrigeration cycle apparatus according to Embodiment 4 of the present invention.
[Fig. 13] Fig. 13 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 5 of the present invention.
[Fig. 14] Fig. 14 is a P-h diagram illustrating an action state in an operation in Fig. 13.
[Fig. 15] Fig. 15 is a system configuration diagram of the refrigeration cycle apparatus according to Embodiment 5 of the present invention.
[Fig. 16] Fig. 16 is a flowchart illustrating a control procedure of a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 5 of the present invention.
[Fig. 17] Fig. 17 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 6 of the present invention.
[Fig. 18] Fig. 18 is a refrigerant circuit diagram of Modification 1 of the refrigeration cycle apparatus according to Embodiment 6 of the present invention.
[Fig. 19] Fig. 19 is a refrigerant circuit diagram of Modification 2 of the refrigeration cycle apparatus according to Embodiment 6 of the present invention. Description of Embodiments

[0009] A refrigeration cycle apparatus according to Embodiments of the present invention will be described below with reference to the drawings, for example. Here, in the following drawings including Fig. 1, components denoted by the same reference numerals are the same or corresponding components, and this is common throughout Embodiments to be described below. Then, the forms of components described throughout the specification are merely illustrative, and forms are not limited to the forms described in the specification. In particular, combinations of components are not limited to only those in each Embodiment, and a component described in one Embodiment can be used in another Embodiment. In addition, high and low levels of temperature, pressure, or other measurements are not determined in relation to an absolute value in particular, but are relatively determined in accordance with the state or action of a system or an apparatus, for example.
[0010] Furthermore, the case where the refrigeration cycle apparatus is used for a heat pump water heater is taken as an example below to describe Embodiments.

Embodiment 1

[0011] Fig. 1 is a refrigerant circuit diagram of a refrigeration cycle apparatus according to Embodiment 1 of the present invention and illustrates a state provided while a heating operation (hot-water supply operation) of raising the temperature of water on a load side is being performed.

[0012] The refrigeration cycle apparatus according to Embodiment 1 includes a main circuit 30 in which a compressor 1, a four-way valve 2, a condenser 3, a main expansion valve 4, and an evaporator 5 are connected in a circle, and through which refrigerant circulates, a bypass 40, and a discharged gas bypass valve 7 serving as a negative pressure regulating valve that regulates a flow rate in the bypass 40.

[0013] The compressor 1 is constituted by, for example, an inverter compressor capable of controlling capacity, sucks low-temperature low-pressure gas refrigerant, compresses the refrigerant to turn it into a high-temperature high-pressure gas refrigerant state, and discharges thereof.

[0014] The four-way valve 2 switches a direction in which the high-temperature high-pressure gas refrigerant discharged from the compressor 1 flows to the direction of the condenser 3 or the evaporator 5.

[0015] The condenser 3 is constituted by a plate-type heat exchanger and exchanges heat between refrigerant flowing through the main circuit 30 and a medium to be subjected to heat exchange supplied from a cooling load (not illustrated) to transfer heat.

[0016] The main expansion valve 4 reduces the pressure of high-pressure refrigerant to turn the refrigerant into low-pressure two-phase refrigerant.

[0017] The evaporator 5 is constituted by, for example, a plate-fin-type heat exchanger and exchanges heat between refrigerant and air to evaporate the refrigerant.

[0018] The bypass 40 includes a discharged gas bypass 6 and a suction bypass 8, and is a circuit that combines a flow of part of refrigerant discharged from the compressor 1 and a flow of refrigerant having flowed out of the condenser 3 into a combined flow to allow the combined flow to flow into a suction side of the compressor 1.

[0019] The discharged gas bypass 6 bypasses part of discharged refrigerant discharged from the compressor 1 to the suction side of the compressor 1. The discharged gas bypass valve 7 is provided in the discharged gas bypass 6 and regulates a bypass flow rate of discharged gas to be passed through the discharged gas bypass 6. An increase in the opening degree of the discharged gas bypass valve 7 increases a flow rate of refrigerant passing through the discharged gas bypass 6 and returning to the suction side of the compressor 1 and increases a compressor suction pressure. On the other hand, a reduction in the opening degree of the discharged gas bypass valve 7 reduces a flow rate of refrigerant passing through the discharged gas bypass 6 and returning to the suction side of the compressor 1 and reduces a compressor suction pressure.

[0020] The suction bypass 8 combines a flow of high-pressure refrigerant at an outlet of the condenser 3 into a flow in the discharged gas bypass 6 to allow the flow to flow into the suction side of the compressor 1. A suction bypass valve 9 is provided in the suction bypass 8 and regulates a flow rate of refrigerant to be passed through the suction bypass 8. An increase in the opening degree of the suction bypass valve 9 increases a flow rate of high-pressure refrigerant passing through the suction bypass 8 and flowing into the suction side of the compressor 1 and thus reduces a compressor suction superheat degree. On the other hand, a reduction in the opening degree of the suction bypass valve 9 reduces a flow rate of high-pressure refrigerant flowing from the suction bypass 8 into the suction side of the compressor 1 and thus increases a compressor suction superheat degree.

[0021] Here, in Embodiment 1, refrigerant containing HFO-1234yf refrigerant or HFO-1234ze refrigerant is used as refrigerant. Refrigerant may be a single refrigerant of HFO-1234yf, a single refrigerant of HFO-1234ze, or a refrigerant mixture containing HFO-1234yf or HFO-1234ze. In the case of a refrigerant mixture, R32 can be used, for example. A global warming potential (GWP) of the HFO-1234yf refrigerant or the HFO-1234ze refrigerant is "4", which is lower than "2090" of existing R410A refrigerant and "1770" of R407C refrigerant, and thus the HFO-1234yf refrigerant or the HFO-1234ze refrigerant is refrigerant that has less impact on the global environment.

[0022] Next, the action of a refrigeration cycle of the refrigeration cycle apparatus according to Embodiment 1 will be described with reference to Fig. 1.

[0023] First, a normal hot-water supply operation will be described.

[0024] During a normal hot-water supply operation, the discharged gas bypass valve 7 and the suction bypass valve 9 are fully closed, and refrigerant does not flow through the discharged gas bypass 6 and the suction bypass 8. In the normal hot-water supply operation, refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure refrigerant discharged from the compressor 1 flows into the condenser 3 via the four-way valve 2. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant. The high-pressure liquid refrigerant having flowed out of the condenser 3 flows into the main expansion valve 4 and is reduced in pressure and expanded to turn into low-temperature low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant having flowed out of the main expansion valve 4 flows into the evaporator 5, cools air serving as a medium to be subjected to heat exchange, and evaporates to turn into low-temperature low-pressure gas refrigerant. The low-temperature low-pressure gas refrigerant having flowed out of the evaporator 5 passes through the four-way valve 2 again and then is sucked into the compressor 1 again.

[0025] Here, for R410A refrigerant and R407C refrigerant that have been used, and for HFO-1234yf refrigerant and

HFO-1234ze that are used in Embodiment 1, relationships between saturation temperatures and saturated vapor pressures will be described.

[0026] Fig. 2 is a graph illustrating comparisons of relationships between saturation temperatures and saturated vapor pressures of various types of refrigerant. Here, as various types of refrigerant, R410A refrigerant, R407C refrigerant, HFO-1234yf refrigerant, and HFO-1234ze are illustrated. In Fig. 2, the horizontal axis represents saturation temperature [DEGREES C], and the vertical axis represents saturated vapor pressure [MPa (abs)].

[0027] According to Fig. 2, in terms of saturated vapor pressure, the HFO-1234yf refrigerant used in Embodiment 1 is lower than the R410A refrigerant and R407C refrigerant that have been used. Thus, when a hot-water supply operation is performed in a very cold area where an outdoor air temperature is equal to or less than -25 degrees C, for example, it is conceivable that an evaporating temperature may fall below a saturated vapor temperature of -29.5 degrees C at an atmospheric pressure, resulting in a negative pressure operation in which a compressor suction pressure is equal to or less than the atmospheric pressure. When the compressor suction pressure becomes negative, air is sucked into the refrigeration cycle, resulting in the occurrence of a disadvantage, such as a malfunction of the refrigeration cycle.

[0028] Thus, the refrigeration cycle apparatus according to Embodiment 1 performs a negative pressure prevention operation of continuing a hot-water supply operation with a compressor suction pressure being equal to or greater than a negative pressure even under low outdoor air temperature conditions.

[0029] Next, the action of a refrigeration cycle in a negative pressure prevention operation will be described with reference to the refrigerant circuit diagram of Fig. 1 and the following P-h diagram of Fig. 3.

[0030] Fig. 3 is a P-h diagram illustrating an action state in a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 1 of the present invention. In Fig. 3, [1] to [5] respectively indicate refrigerant states at positions of [1] to [5] in Fig. 1. Note that, during the negative pressure prevention operation, the opening degree of the main expansion valve 4 is in a substantially-closed state. An opening degree being in the "substantially-closed" state refers to not only an opening degree being in a fully-closed state but also such an exceedingly small opening degree that has no adverse effect in preventing negative pressure. That is, an opening degree being in the "substantially-closed" state corresponds to an opening degree being in a fully-closed state or in a state close to the fully-closed state. When the main expansion valve 4 is open during a heating operation under low outdoor air temperature conditions, refrigerant flows into the evaporator 5, resulting in a reduction in compressor suction pressure. Thus, in the negative pressure prevention operation, the main expansion valve 4 is closed so that refrigerant does not flow into the evaporator 5.

[0031] In a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 1, refrigerant ([1]) being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure refrigerant ([2]) discharged from the compressor 1 is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the discharged gas bypass 6 and is reduced in pressure by the discharged gas bypass valve 7 to turn into high-temperature low-pressure gas refrigerant ([3]), and it is bypassed to the suction side of the compressor 1. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3 via the four-way valve 2. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant ([4]).

[0032] The high-pressure liquid refrigerant having flowed out of the condenser 3 flows into the suction bypass 8 and is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure two-phase gas-liquid refrigerant ([5]). A flow of the high-temperature low-pressure gas ([3]) that has been reduced in pressure by the discharged gas bypass valve 7 and a flow of the low-temperature low-pressure two-phase gas-liquid refrigerant ([5]) that has been reduced in pressure and expanded by the suction bypass valve 9 combine to form a flow of low-temperature low-pressure gas refrigerant ([1]), and the flow is sucked into the compressor 1 again. Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur.

[0033] Here, a general description of a negative pressure prevention operation will be given.

[0034] The negative pressure prevention operation is started when an operation state in which a compressor suction pressure is close to a negative pressure is entered, and is an operation that causes little refrigerant to flow into the evaporator 5 and causes most of high-pressure refrigerant having flowed out of the condenser 3 to flow into the suction bypass 8. Then, the discharged gas bypass valve 7 is controlled so that a compressor suction pressure becomes higher than the negative pressure, thereby preventing negative pressure. In Embodiment 1, in addition to control of the discharged gas bypass valve 7, the suction bypass valve 9 is also controlled so that a compressor suction superheat degree is put into an appropriate state.

[0035] Fig. 4 is a system configuration diagram of the refrigeration cycle apparatus according to Embodiment 1 of the present invention. Fig. 5 is a flowchart illustrating a control procedure of a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 1 of the present invention.

[0036] As illustrated in Fig. 4, the refrigeration cycle apparatus according to Embodiment 1 includes a controller 20, a compressor suction pressure sensor 21, and a compressor suction temperature sensor 22. Note that the other components are the same as those in Fig. 1.

[0037] The controller 20 controls the entire refrigeration cycle apparatus. The controller 20 is constituted by a microcomputer, for example, and includes a CPU, a RAM, a ROM, and other components. In the ROM, a control program and a program corresponding to the flowchart of Fig. 5 are stored.

[0038] The compressor suction pressure sensor 21 and the compressor suction temperature sensor 22 are connected to the controller 20 so that detection signals from the respective sensors can be received. Based on, for example, these detection signals, the controller 20 controls the opening degree of the main expansion valve 4, the opening degree of the discharged gas bypass valve 7, and the opening degree of the suction bypass valve 9, for example. The controller 20 also controls, based on, for example, detection signals from the respective sensors 21 and 22, various operations including a negative pressure prevention operation.

[0039] Next, functional components of the controller 20 will be described. The controller 20 includes a negative pressure prevention control unit 20a and a superheat degree control unit 20b. The negative pressure prevention control unit 20a performs a negative pressure prevention operation of controlling the discharged gas bypass valve 7 to prevent a suction pressure of the compressor 1 from becoming negative. The superheat degree control unit 20b regulates the opening degree of the suction bypass valve 9 so that a degree of superheat of gas to be sucked into the compressor 1 becomes a setting value set in advance. The negative pressure prevention control unit 20a and the superheat degree control unit 20b are functionally configured by the CPU and the control program.

[0040] Next, a control action in a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 1 will be described with reference to Figs. 4 and 5.

[0041] The controller 20 acquires a compressor suction pressure Ps detected by the compressor suction pressure sensor 21 (S1). Then, the controller 20 compares the compressor suction pressure Ps with a setting value 1 (It is, for example, 0.01 MPa (G), which is a setting value representing at least a positive pressure.) that has been set in advance and is an upper limit pressure at which a negative pressure prevention operation is started (S2). While the compressor suction pressure Ps is equal to or greater than the setting value 1, the controller 20 returns to step S1, and a normal hot-water supply operation is continued. On the other hand, when the compressor suction pressure Ps falls below the setting value 1, the controller 20 determines that the refrigeration cycle apparatus is in an operation state in which an outdoor air temperature is low and the compressor suction pressure is close to a negative pressure, and starts the negative pressure prevention operation (S3).

[0042] In the negative pressure operation, first, the controller 20 substantially closes the main expansion valve 4 (its opening degree is reduced to an opening degree being in a fully-closed state or in a state close to the fully-closed state) (S4). Subsequently, the controller 20 compares a setting value 2 (It is, for example, 0.02 MPa (G), which is a setting value representing at least a positive pressure.) that has been set in advance as a target value of a compressor suction pressure with the compressor suction pressure Ps (S5). Then, when the compressor suction pressure Ps is lower than the setting value 2 (> the setting value 1), the controller 20 increases the opening degree of the discharged gas bypass valve 7 (S6). Thus, the compressor suction pressure Ps rises and approaches the setting value 2. On the other hand, when the compressor suction pressure Ps is higher than the setting value 2, the opening degree of the discharged gas bypass valve 7 is reduced (S7). Thus, the compressor suction pressure Ps falls and approaches the setting value 2. Note that, although not illustrated in Fig. 5, when the compressor suction pressure Ps is equal to the setting value 2, the opening degree of the discharged gas bypass valve 7 may remain unchanged.

[0043] Subsequently, the controller 20 acquires a compressor suction temperature Ts detected by the compressor suction temperature sensor 22. Then, the controller 20 calculates a compressor suction superheat degree SHs by using the acquired compressor suction temperature Ts (S9). That is, the controller 20 calculates a saturation temperature f(Ps) of the compressor suction pressure Ps and subtracts the saturation temperature f(Ps) of the compressor suction pressure Ps from the compressor suction temperature Ts to get a compressor suction superheat degree SHs.

[0044] Subsequently, the controller 20 compares the calculated compressor suction superheat degree SHs with a setting value 3 (for example, 5 K) that has been set in advance as a target value of a compressor suction superheat degree (S10). Then, when the compressor suction superheat degree SHs is lower than the setting value 3, the controller 20 reduces the opening degree of the suction bypass valve 9 (S11). Thus, the compressor suction superheat degree SHs rises and approaches the setting value 3. On the other hand, when the compressor suction superheat degree SHs is higher than the setting value 3, the opening degree of the suction bypass valve 9 is increased (S12). Thus, the compressor suction superheat degree SHs falls and approaches the setting value 3. Note that, although not illustrated in Fig. 5, when the compressor suction superheat degree SHs is equal to the setting value 3, the opening degree of the suction bypass valve 9 may remain unchanged. Then, after the process of S11 or S12, the controller 20 returns to S5 and repeatedly performs control so that the compressor suction pressure Ps and the compressor suction superheat degree SHs respectively become equal to the corresponding setting value 2 and setting value 3.

[0045] As described above, when the refrigeration cycle apparatus according to Embodiment 1 enters an operation state in which an outdoor air temperature is low and a compressor suction pressure is close to a negative pressure, the refrigeration cycle apparatus continues a hot-water supply operation with the main expansion valve 4 being fully closed without evaporation of refrigerant in the evaporator 5. Then, the compressor suction pressure is controlled by using the opening degree of the discharged gas bypass valve 7, and a compressor suction superheat degree is also controlled by using the opening degree of the suction bypass valve 9. This prevents the compressor suction pressure from becoming negative and also enables the hot-water supply operation to continue with the compressor suction superheat degree being appropriate. Thus, even when an outdoor air temperature falls, a disadvantage, such as a malfunction due to suction of air, can be avoided. Furthermore, in a water heater, a hot-water supply operation of raising the temperature of water does not have to be stopped even under low outdoor air temperature conditions, thus making it possible to prevent water pipes from freezing, for example.

Embodiment 2

[0046] In Embodiment 2, a two-way valve is further included in the structure in Embodiment 1 illustrated in Fig. 1. Note that the other components are the same as those in Fig. 1. A description will be given below with emphasis on a respect in which Embodiment 2 differs from Embodiment 1.

[0047] Fig. 6 is a system configuration diagram of the refrigeration cycle apparatus according to Embodiment 2 of the present invention. Fig. 7 is a flowchart illustrating a control procedure of a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 2 of the present invention.

[0048] As illustrated in Fig. 6, the refrigeration cycle apparatus according to Embodiment 2 further includes a two-way valve 10 in addition to the structure in Embodiment 1.

[0049] The two-way valve 10 is disposed between the four-way valve 2 and the evaporator 5 and interrupts the flow of refrigerant between the four-way valve 2 and the evaporator 5 by closing the two-way valve 10.

[0050] Next, the control action of the refrigeration cycle apparatus according to Embodiment 2 will be described with reference to Figs. 6 and 7. Note that a normal hot-water supply operation is the same as that in Embodiment 1, and thus a description thereof is omitted. Only a negative pressure prevention operation will be described.

[0051] A negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 2 differs from that in Embodiment 1 in that a step of closing the two-way valve 10 (S21) is further included in the flowchart in Embodiment 1 illustrated in Fig. 5, and the other steps are the same as those in Embodiment 1. It is only necessary that the step of closing the two-way valve 10 be provided between step S3 and step S5.

[0052] As described above, the refrigeration cycle apparatus according to Embodiment 2 produces the same effect as that in Embodiment 1 and also produces the following effect. That is, closing the two-way valve 10 during a negative pressure prevention operation can prevent low-pressure high-temperature refrigerant (refrigerant indicated by a dotted arrow in Fig. 6) having flowed out of the discharged gas bypass valve 7 from flowing into the cold evaporator 5 via the four-way valve 2, condensing, and accumulating. This does not result in any lack of refrigerant circulating through the discharged gas bypass 6 and the suction bypass 8 and enables the negative pressure prevention operation to continue.

Embodiment 3

[0053] In Embodiment 3, an ejector and a suction pipe are further included in the structure in Embodiment 1 illustrated in Fig. 1. Note that the other components are the same as those in Fig. 1. A description will be given below with emphasis on a respect in which Embodiment 3 differs from Embodiment 1.

[0054] Fig. 8 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 3 of the present invention.

[0055] An ejector 11 is disposed on a downstream side of the discharged gas bypass valve 7 of the discharged gas bypass 6 and sucks refrigerant on an evaporator 5 side via a suction pipe 12.

[0056] Fig. 9 is a schematic view of the ejector of Fig. 8.

[0057] The ejector 11 is constituted by three sections: a nozzle 11 a, an expansion section 11b, and a diffuser 11c. A main flow flowing in from an inlet is throttled by the nozzle 11a and put into a state in which its flow velocity at the expansion section 11b is higher than that at the inlet. Assuming that the pressure, flow velocity, and density of refrigerant at the inlet are respectively P1, v1, and p1, and that the pressure, flow velocity, and density of refrigerant at the expansion section 11b are respectively P2, v2, and p2, the following relationship holds based on Bernoulli's equation.

[Math. 1]

$$P1+\frac{1}{2}\rho 1 v1^2 = P2+\frac{1}{2}\rho 2 v2^2$$

[0058] Here, because the relationship between the flow velocity v2 at the expansion section 11 b and the flow velocity v1 at the inlet is v2 > v1, the relationship between the respective pressures is P2 < P1, a pressure differential of P1 - P2 is created in a refrigerant suction section 11d, and refrigerant is sucked.

[0059] Next, the action of a refrigeration cycle of the refrigeration cycle apparatus according to Embodiment 3 will be described with reference to Fig. 8. Note that the action of a refrigeration cycle in a normal hot-water supply operation is the same as that in Embodiment 1, and thus a description thereof is omitted. Only a negative pressure prevention operation will be described. In the negative pressure prevention operation, the fact that the main expansion valve 4 is substantially closed is the same as that in Embodiment 1.

[0060] In a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 3, refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure refrigerant discharged from the compressor 1 is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the discharged gas bypass 6 and is reduced in pressure by the discharged gas bypass valve 7 to turn into high-temperature low-pressure gas refrigerant, and it flows into the ejector 11. In the ejector 11, a refrigerant pressure decreases as a refrigerant flow velocity increases, and refrigerant on the evaporator 5 side is sucked via the suction pipe 12 connected to the refrigerant suction section 11 d.

[0061] Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3 via the four-way valve 2. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant. The high-pressure liquid refrigerant having flowed out of the condenser 3 flows into the suction bypass 8 and is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure two-phase gas-liquid refrigerant. A flow of the high-temperature low-pressure gas that has been reduced in pressure by the discharged gas bypass valve 7 and passed through the ejector 11 and a flow of the low-temperature low-pressure two-phase gas-liquid refrigerant that has been reduced in pressure and expanded by the suction bypass valve 9 combine to form a flow of low-temperature low-pressure gas refrigerant, and the flow is sucked into the compressor 1 again.

[0062] As described above, the refrigeration cycle apparatus according to Embodiment 3 produces the same effect as that in Embodiment 1 and also produces the following effect. That is, even when low-pressure high-temperature refrigerant having flowed out of the discharged gas bypass valve 7 flows into the cold evaporator 5 via the four-way valve 2 during a negative pressure prevention operation, the refrigerant having flowed to the evaporator 5 side is sucked by the ejector 11 to enable the refrigerant to be drawn back to the discharged gas bypass 6. Thus, refrigerant having flowed out of the discharged gas bypass valve 7 and flowed into the evaporator 5 can be prevented from condensing and accumulating in the evaporator 5. This does not result in any lack of refrigerant circulating through the discharged gas bypass 6 and the suction bypass 8 and enables the negative pressure prevention operation to continue.

Embodiment 4

[0063] In Embodiment 4, a receiver is further included in the structure in Embodiment 1 illustrated in Fig. 1. Note that the other components are the same as those in Fig. 1. A description will be given below with emphasis on a respect in which Embodiment 4 differs from Embodiment 1.

[0064] Fig. 10 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 4 of the present invention.

[0065] A receiver 13 is disposed on a pipe connecting the condenser 3 and the suction bypass valve 9 and stores excess refrigerant caused during an operation.

[0066] Next, the action of a refrigeration cycle according to Embodiment 4 will be described with reference to Fig. 10. Note that a normal hot-water supply operation is the same as that in Embodiment 1, and thus a description thereof is omitted. Only a negative pressure prevention operation will be described. In the negative pressure prevention operation, the fact that the main expansion valve 4 is substantially closed is the same as that in Embodiment 1.

[0067] In a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 4, refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure refrigerant discharged from the compressor 1 is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the discharged gas bypass 6 and is reduced in pressure by the discharged gas bypass valve 7 to turn into high-temperature low-pressure gas refrigerant, and it is bypassed to the suction side of the compressor 1. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3 via the four-way valve 2. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant. The high-pressure liquid refrigerant having flowed out of the condenser 3 flows into the suction bypass 8 via the receiver 13 and is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure two-phase gas-liquid refrigerant. A flow of the high-temperature low-pressure gas that has been reduced in pressure by the discharged gas bypass valve 7 and a flow of the low-temperature low-pressure two-phase gas-liquid refrigerant that has been reduced in pressure and expanded by the suction bypass valve 9 combine to form a flow of low-temperature low-pressure gas refrigerant, and the flow is sucked into the compressor 1 again.

[0068] Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur. Thus, the evaporator 5 is not used in the negative pressure prevention operation, and the necessary amount of refrigerant is smaller than that in a normal hot-water supply operation. This causes excess refrigerant in the negative pressure prevention operation. In Embodiment 4, however, excess refrigerant can be stored in the receiver 13.

[0069] As described above, the refrigeration cycle apparatus according to Embodiment 4 produces the same effect as that in Embodiment 1 and also produces the following effect. That is, excess refrigerant can be stored in the receiver 13 during a negative pressure prevention operation, thereby preventing an operation in which liquid flows back to the suction side of the compressor 1 and enabling a highly reliable negative pressure prevention operation to continue.

[0070] Although Embodiment 4 presents the structure including a refrigerant storage container (the receiver 13 herein), the disposition of the refrigerant storage container is not limited to the disposition illustrated in Fig. 10, and modifications can be made as described in the following Modifications 1 and 2.

<Modification 1>

[0071] Fig. 11 is a refrigerant circuit diagram of a refrigeration cycle apparatus illustrating Modification 1 of the refrigeration cycle apparatus according to Embodiment 4 of the present invention.

[0072] As illustrated in Fig. 11, a refrigerant circuit of Modification 1 of the refrigeration cycle apparatus according to Embodiment 4 includes a receiver 13a and a check valve 14 in place of the receiver 13 of Fig. 10. Note that the other components are the same as those in Fig. 10.

[0073] The receiver 13a is a refrigerant storage container that stores excess refrigerant caused during an operation. The receiver 13a is provided in parallel with the main circuit 30 on an outlet side of the condenser 3. In other words, the receiver 13a is provided in parallel with a pipe between a portion where an upstream end of the suction bypass 8 meets the main circuit 30 and the outlet of the condenser 3.

[0074] The check valve 14 prevents refrigerant from flowing from a main expansion valve 4 side into the receiver 13a. In some cases, frost forms on the evaporator 5 during a hot-water supply operation. In such a case, a reverse defrosting operation is performed. The reverse defrosting operation is an operation of removing frost forming on the evaporator 5 by switching the four-way valve 2 in directions indicated by dotted lines in Fig. 11 to supply high-temperature high-pressure gas refrigerant discharged from the compressor 1 to the evaporator 5. The check valve 14 prevents refrigerant from flowing into the receiver 13a during the reverse defrosting operation.

[0075] Next, the action of a refrigeration cycle of Modification 1 of the refrigeration cycle apparatus according to Embodiment 4 will be described with reference to Fig. 11. Note that a normal hot-water supply operation is the same as that in Embodiment 1, and only a negative pressure prevention operation will be described. During the negative pressure prevention operation, the fact that the main expansion valve 4 is substantially closed is the same as that in Embodiment 1.

[0076] In a negative pressure prevention operation in Modification 1, refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure refrigerant discharged from the compressor 1 is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the discharged gas bypass 6 and is reduced in pressure by the discharged gas bypass valve 7 to turn into high-temperature low-pressure gas refrigerant, and it is bypassed to the suction side of the compressor 1. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3 via the four-way valve 2. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant.

[0077] The high-pressure refrigerant having flowed out of the condenser 3 is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the suction bypass 8 via the main circuit 30, and refrigerant that is to flow through the other flow path is condensed and stored in the receiver 13a. The high-pressure refrigerant having flowed into the suction bypass 8 is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure two-phase gas-liquid refrigerant. A flow of the high-temperature low-pressure gas that has been reduced in pressure by the discharged gas bypass valve 7 and a flow of the low-temperature low-pressure two-phase gas-liquid refrigerant that has been reduced in pressure and expanded by the suction bypass valve 9 combine to form a flow of low-temperature low-pressure gas refrigerant, and the flow is sucked into the compressor 1 again.

[0078] Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur. In the negative pressure prevention operation, the evaporator 5 is not used, and the necessary amount of refrigerant is thus smaller than that in a normal hot-water supply operation, thereby causing excess refrigerant. In Modification 1, however, excess refrigerant can be stored in the receiver 13a.

[0079] As described above, in Modification 1 of the refrigeration cycle apparatus according to Embodiment 4, the receiver 13a is provided in parallel with the main circuit 30 on the outlet side of the condenser 3. This enables excess refrigerant to be stored in the receiver 13a even when refrigerant at the outlet of the condenser 3 is in a two-phase state. Thus, during a negative pressure prevention operation in which excess refrigerant is caused, an operation in which liquid flows back to the suction side of the compressor 1 is prevented, thereby enabling a highly reliable negative pressure prevention operation to continue.

<Modification 2>

[0080] Fig. 12 is a refrigerant circuit diagram of a refrigeration cycle apparatus illustrating Modification 2 of the refrigeration cycle apparatus according to Embodiment 4 of the present invention.

[0081] As illustrated in Fig. 12, a refrigerant circuit of Modification 2 of the refrigeration cycle apparatus according to Embodiment 4 includes an accumulator 15 in place of the receiver 13 of Fig. 10. Note that the other components are the same as those in Fig. 10.

[0082] The accumulator 15 is provided on the suction side of the compressor 1 and is a refrigerant storage container that stores excess refrigerant caused during an operation.

[0083] Next, the action of a refrigeration cycle of Modification 2 of the refrigeration cycle apparatus according to Embodiment 4 will be described with reference to Fig. 12. Note that a normal hot-water supply operation is the same as that in Embodiment 1, and only a negative pressure prevention operation will be described.

[0084] In a negative pressure prevention operation in Modification 2, refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure refrigerant discharged from the compressor 1 is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the discharged gas bypass 6 and is reduced in pressure by the discharged gas bypass valve 7 to turn into high-temperature low-pressure gas refrigerant, and it is bypassed to the suction side of the compressor 1. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3 via the four-way valve 2. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant.

[0085] The high-pressure refrigerant having flowed out of the condenser 3 flows into the suction bypass 8, and the high-pressure refrigerant having flowed into the suction bypass 8 is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure two-phase gas-liquid refrigerant. A flow of the high-temperature low-pressure gas that has been reduced in pressure by the discharged gas bypass valve 7 and a flow of the low-temperature low-pressure two-phase gas-liquid refrigerant that has been reduced in pressure and expanded by the suction bypass valve 9 combine to form a flow of low-temperature low-pressure refrigerant, and the flow is sucked into the compressor 1 again via the accumulator 15.

[0086] Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur. In the negative pressure prevention operation, the evaporator 5 is not used, and the necessary amount of refrigerant is thus smaller than that in a normal hot-water supply operation, thereby causing excess refrigerant. In Modification 2, however, excess refrigerant can be stored in the accumulator 15.

[0087] As described above, in Modification 2 of the refrigeration cycle apparatus according to Embodiment 4, the accumulator 15 is provided on the suction side of the compressor 1, thereby enabling excess refrigerant to be stored in the accumulator 15 during a negative pressure prevention operation in which excess refrigerant is caused. This prevents an operation in which liquid flows back to the suction side of the compressor 1, thereby enabling a highly reliable negative pressure prevention operation to continue.

Embodiment 5

[0088] In Embodiments 1 to 4 described above, part of refrigerant discharged from the compressor 1 toward the condenser 3 is caused to flow into the discharged gas bypass 6 so that it is diverted from the main circuit 30, and the diverted refrigerant is caused to flow back to the suction side of the compressor 1. Then, in causing the diverted refrigerant to flow back to the suction side of the compressor 1, a flow of the diverted refrigerant is combined with a flow of refrigerant flowing through the suction bypass 8 on a downstream side of the suction bypass valve 9 and then caused to flow back. In contrast to this, in Embodiment 5, in causing diverted refrigerant that has been diverted from the main circuit 30 to flow back to the suction side of the compressor 1, a flow of the diverted refrigerant is combined with a flow of refrigerant that is to flow through the suction bypass 8 on an upstream side of the suction bypass valve 9 and then caused to flow back.

[0089] Fig. 13 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 5 of the present invention and illustrates a state provided while a hot-water supply operation of raising the temperature of water on a load side is being performed. Furthermore, Fig. 14 is a P-h diagram illustrating an action state in an operation in Fig. 13.

[0090] In Embodiment 5, the discharged gas bypass 6 and the discharged gas bypass valve 7 are removed from the structure in Embodiment 1 illustrated in Fig. 1, whereas a condenser bypass 16 that bypasses the condenser 3 and a condenser bypass valve 17 that regulates a flow rate in the condenser bypass 16 are included. A bypass 41 in Embodiment 5 includes the condenser bypass 16 and the suction bypass 8, and is a circuit that combines a flow of refrigerant having flowed out of the condenser bypass 16 (part of refrigerant discharged from the compressor 1) and a flow of refrigerant having flowed out of the condenser 3 into a combined flow to allow the combined flow to flow into the suction side of the compressor 1 via the suction bypass 8. In the bypass 41, the suction bypass valve 9 constitutes the negative pressure regulating valve according to the present invention.

[0091] The condenser bypass 16 bypasses part of discharged refrigerant discharged from the compressor 1 to the outlet side of the condenser 3.

[0092] The condenser bypass valve 17 regulates a bypass flow rate of discharged gas to be passed through the condenser bypass 16.

[0093] Next, the action of a refrigeration cycle of the refrigeration cycle apparatus according to Embodiment 5 will be described with reference to Fig. 13. Note that, during a normal hot-water supply operation, the condenser bypass valve 17 and the suction bypass valve 9 are fully closed, and refrigerant does not flow through the condenser bypass 16 and the suction bypass 8. Hence, the action of a refrigeration cycle during a normal hot-water supply operation in Embodiment 5 is the same as that in Embodiment 1. Thus, only a negative pressure prevention operation will be described. During the negative pressure prevention operation, the fact that the main expansion valve 4 is substantially closed is the same as that in Embodiment 1.

[0094] Next, an action in a negative pressure prevention operation will be described with reference to the refrigerant circuit diagram of Fig. 13 and the P-h diagram of Fig. 14. In Fig. 14, [1] to [5] respectively indicate refrigerant states at positions of [1] to [5] in Fig. 13.

[0095] In a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 5, refrigerant ([1]) being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas ([2]), and discharged. The high-temperature high-pressure gas refrigerant discharged from the compressor 1 passes through the four-way valve 2 and then is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the condenser bypass 16 and is reduced in pressure ([3]) by the condenser bypass valve 17, and then it flows out of the condenser bypass 16. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant ([4]).

[0096] A flow of the high-temperature high-pressure gas refrigerant having flowed out of the condenser bypass 16 and a flow of the high-pressure liquid refrigerant having flowed out of the condenser 3 combine to form a flow of high-pressure high-quality two-phase refrigerant ([5]). The two-phase refrigerant flows into the suction bypass 8 and is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure gas refrigerant ([1]), and the low-temperature low-pressure gas refrigerant is sucked into the compressor 1 again. Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur.

[0097] In Embodiments 1 to 4 described above, a compressor suction pressure is controlled by the discharged gas bypass valve 7. In contrast to this, with respect to the flow of refrigerant in Embodiment 5, as illustrated in Fig. 14, a flow of refrigerant ([3]) having flowed out of the condenser bypass 16 and a flow of refrigerant ([4]) having flowed out of the condenser 3 combine to form a combined flow, and refrigerant in the combined flow is reduced in pressure by the suction bypass valve 9 and sucked into the compressor 1. Thus, in Embodiment 5, a compressor suction pressure is controlled by the suction bypass valve 9.

[0098] Fig. 15 is a system configuration diagram of the refrigeration cycle apparatus according to Embodiment 5 of the present invention.

[0099] As illustrated in Fig. 15, the refrigeration cycle apparatus according to Embodiment 5 differs from that illustrated in Fig. 4 in that the controller 20 is connected in such a manner as to be able to control the condenser bypass valve 17 in place of the discharged gas bypass valve 7 in the system configuration in Embodiment 1 illustrated in Fig. 4. Furthermore, as functional components of the controller 20, the controller 20 includes a negative pressure prevention control unit 20A and a superheat degree control unit 20B. The negative pressure prevention control unit 20A performs a negative pressure prevention operation of controlling the opening degree of the suction bypass valve 9 to prevent a suction pressure of the compressor 1 from becoming negative. The superheat degree control unit 20B regulates the opening degree of the condenser bypass valve 17 so that a degree of superheat of gas to be sucked into the compressor 1 becomes a setting value set in advance. The negative pressure prevention control unit 20A and the superheat degree control unit 20B are functionally configured by the CPU and the control program. Configurations other than these are the same as those illustrated in Fig. 4.

[0100] Fig. 16 is a flowchart illustrating a control procedure of a negative pressure prevention operation in the refrigeration cycle apparatus according to Embodiment 5 of the present invention. In comparison with the flowchart in Embodiment 1 illustrated in Fig. 5 described above, the flowchart in Embodiment 5 illustrated in Fig. 16 differs from that in Embodiment 1 in the following respects. That is, control of the opening degree of the discharged gas bypass valve 7 in steps S6 and S7 in Fig. 5 is replaced with control of the opening degree of the suction bypass valve 9 in steps S6a and S7a in Fig. 16. Furthermore, control of the opening degree of the suction bypass valve 9 in steps S11 and S12 in Fig. 5 is replaced with control of the opening degree of the condenser bypass valve 17 in Fig. 16. The other steps are the same as those in the control flowchart of Fig. 16. A description will be given below with emphasis on a respect in which control of the negative pressure prevention operation in Embodiment 5 differs from that in Embodiment 1.

[0101] In Embodiment 5, as a result of a comparison of a compressor suction pressure Ps and a setting value 2 set in advance in step S5, when the compressor suction pressure Ps is lower than the setting value 2, the opening degree of the suction bypass valve 9 is increased (S6a). Thus, the compressor suction pressure Ps rises and approaches the setting value 2. On the other hand, when the compressor suction pressure Ps is higher than the setting value 2, the opening degree of the suction bypass valve 9 is reduced (S7a). Thus, the compressor suction pressure Ps falls and approaches the setting value 2.

[0102] Furthermore, in Embodiment 5, as a result of a comparison of a compressor suction superheat degree SHs and a setting value 3 that has been set in advance as a target value of a compressor suction superheat degree in step S10, when the compressor suction superheat degree SHs is lower than the setting value 3, the controller 20 increases the opening degree of the condenser bypass valve 17 (S11a). Thus, the compressor suction superheat degree SHs rises and approaches the setting value 3. On the other hand, when the compressor suction superheat degree SHs is higher than the setting value 3, the opening degree of the condenser bypass valve 17 is reduced (S12a). Thus, the compressor suction superheat degree SHs falls and approaches the setting value 3. Then, after the process of S11a or S12a, the controller 20 returns to S5 and repeatedly performs control so that the compressor suction pressure Ps and the compressor suction superheat degree SHs respectively become equal to the corresponding setting value 2 and setting value 3.

[0103] As described above, in controlling a compressor suction pressure and a compressor suction superheat degree, the refrigeration cycle apparatus according to Embodiment 5 differs from that in Embodiment 1 in bypass valves to be controlled, but can produce the same effect as that in Embodiment 1. That is, when an operation state in which an outdoor air temperature is low and a compressor suction pressure is close to a negative pressure is entered, a hot-water supply operation is continued with the main expansion valve 4 being fully closed without evaporation of refrigerant in the evaporator 5. Then, the compressor suction pressure is controlled by using the opening degree of the suction bypass valve 9, and a suction superheat degree of the compressor 1 is also controlled by using the opening degree of the condenser bypass valve 17. This prevents the compressor suction pressure from becoming negative and also enables the hot-water supply operation to continue with the compressor suction superheat degree being appropriate. Thus, even when an outdoor air temperature falls, a disadvantage, such as a malfunction due to suction of air, can be avoided. Furthermore, in a water heater, a hot-water supply operation of raising the temperature of water does not have to be stopped even under low outdoor air temperature conditions, thus making it possible to prevent water pipes from freezing, for example.

Embodiment 6

[0104] Embodiment 6 corresponds to, so to speak, a combination of Embodiment 5 and Embodiment 4 in which the receiver 13 is included. A description will be given below with emphasis on a respect in which Embodiment 6 differs from Embodiment 5.

[0105] Fig. 17 is a refrigerant circuit diagram of the refrigeration cycle apparatus according to Embodiment 6 of the present invention.

[0106] As illustrated in Fig. 17, a system configuration diagram of the refrigeration cycle apparatus according to Embodiment 6 includes the receiver 13. Note that the other components are the same as those in Embodiment 5 illustrated in Fig. 13.

[0107] The receiver 13 is disposed on a pipe connecting the condenser 3 and the suction bypass valve 9 and stores excess refrigerant caused during an operation.

[0108] Next, the action of a refrigeration cycle according to Embodiment 6 will be described with reference to Fig. 17. Note that a normal hot-water supply operation is the same as that in Embodiment 1, and thus a description thereof is omitted. Only a negative pressure prevention operation will be described.

[0109] Refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure gas refrigerant discharged from the compressor 1 passes through the four-way valve 2 and then is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the condenser bypass 16 and is reduced in pressure by the condenser bypass valve 17, and then it flows out of the condenser bypass 16. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant and flows into the receiver 13. A flow of the high-temperature high-pressure gas refrigerant having flowed out of the condenser bypass 16 and a flow of the high-pressure liquid refrigerant having flowed out of the receiver 13 combine to form a flow of high-pressure high-quality two-phase refrigerant, and the flow flows into the suction bypass 8. The two-phase refrigerant having flowed into the suction bypass 8 is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure gas refrigerant, and the low-temperature low-pressure gas refrigerant is sucked into the compressor 1 again.

[0110] Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur. In the negative pressure prevention operation, the evaporator 5 is not used, and the necessary amount of refrigerant is thus smaller than that in a normal hot-water supply operation, thereby causing excess refrigerant. In Embodiment 6, however, excess refrigerant is stored in the receiver 13.

[0111] As described above, the refrigeration cycle apparatus according to Embodiment 6 produces the same effect as that in Embodiment 5 and also produces the following effect. That is, excess refrigerant can be stored in the receiver 13 during a negative pressure prevention operation, thereby preventing an operation in which liquid flows back to the suction side of the compressor 1 and enabling a highly reliable negative pressure prevention operation to continue.

[0112] Although Embodiment 6 presents the structure including a refrigerant storage container (the receiver 13 herein), the disposition of the refrigerant storage container is not limited to the disposition illustrated in Fig. 17, and modifications can be made as described in the following Modifications 1 and 2.

<Modification 1>

[0113] Fig. 18 is a refrigerant circuit diagram of Modification 1 of the refrigeration cycle apparatus according to Embodiment 6 of the present invention.

[0114] As illustrated in Fig. 18, a refrigerant circuit of Modification 1 of the refrigeration cycle apparatus according to Embodiment 6 includes the receiver 13a and the check valve 14 in place of the receiver 13 of Fig. 17. The other components are the same as those in Fig. 17.

[0115] The receiver 13a is a refrigerant storage container that stores excess refrigerant caused during an operation. The receiver 13a is provided in parallel with the main circuit 30 on the outlet side of the condenser 3. In other words, the receiver 13a is provided in parallel with a pipe between a portion where an upstream end of the condenser bypass 16 meets the main circuit 30 and the outlet of the condenser 3.

[0116] The check valve 14 prevents refrigerant from flowing from the main expansion valve 4 side into the receiver 13a. In some cases, frost forms on the evaporator 5 during a hot-water supply operation. In such a case, a reverse defrosting operation is performed. The reverse defrosting operation is an operation of removing frost forming on the evaporator 5 by switching the four-way valve 2 in directions indicated by dotted lines in Fig. 18 to supply high-temperature high-pressure gas refrigerant discharged from the compressor 1 to the evaporator 5. The check valve 14 prevents the inflow of refrigerant during the reverse defrosting operation.

[0117] Next, the action of a refrigeration cycle of Modification 1 of the refrigeration cycle apparatus according to Embodiment 6 will be described with reference to Fig. 18. Note that a normal hot-water supply operation is the same as that in Embodiment 5, and thus a description thereof is omitted. Only a negative pressure prevention operation will be described. During the negative pressure prevention operation, the fact that the main expansion valve 4 is substantially closed is the same as that in Embodiment 5.

[0118] In a negative pressure prevention operation in Modification 1, refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure gas refrigerant discharged from the compressor 1 passes through the four-way valve 2 and then is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the condenser bypass 16 and is reduced in pressure by the condenser bypass valve 17, and then it flows out of the condenser bypass 16. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant.

[0119] The high-pressure refrigerant having flowed out of the condenser 3 is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the main circuit 30, and refrigerant that is to flow through the other flow path is condensed and stored in the receiver 13a. A flow of the high-pressure refrigerant having flowed into the main circuit 30 combines with a flow of the high-temperature high-pressure gas refrigerant having flowed out of the condenser bypass 16 to form a flow of high-pressure high-quality two-phase refrigerant. The two-phase refrigerant flows into the suction bypass 8 and is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure gas refrigerant, and the low-temperature low-pressure gas refrigerant is sucked into the compressor 1 again.

[0120] Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur. In the negative pressure prevention operation, the evaporator 5 is not used, and the necessary amount of refrigerant is thus smaller than that in a normal hot-water supply operation, thereby causing excess refrigerant. In Embodiment 6, however, excess refrigerant is stored in the receiver 13a.

[0121] As described above, in Modification 1 of the refrigeration cycle apparatus according to Embodiment 6, the receiver 13a is provided in parallel with the main circuit 30 on the outlet side of the condenser 3. This enables excess refrigerant to be stored in the receiver 13a even when refrigerant at the outlet of the condenser 3 is in a two-phase state. Thus, during a negative pressure prevention operation in which excess refrigerant is caused, an operation in which liquid flows back to the suction side of the compressor 1 is prevented, thereby enabling a highly reliable negative pressure prevention operation to continue.

<Modification 2>

[0122] Fig. 19 is a refrigerant circuit diagram of Modification 2 of the refrigeration cycle apparatus according to Embodiment 6 of the present invention.

[0123] As illustrated in Fig. 19, a refrigerant circuit of Modification 1 of the refrigeration cycle apparatus according to Embodiment 6 includes the accumulator 15 in place of the receiver 13 of Fig. 17. Note that the other components are the same as those in Fig. 17.

[0124] The accumulator 15 is provided on the suction side of the compressor 1 and stores excess refrigerant caused during an operation.

[0125] Next, the action of Modification 2 of the refrigeration cycle apparatus according to Embodiment 6 will be described with reference to Fig. 19. Note that a normal hot-water supply operation is the same as that in Embodiment 1, and thus a description thereof is omitted. Only a negative pressure prevention operation will be described.

[0126] In a negative pressure prevention operation in Modification 2, refrigerant being in a low-temperature low-pressure gas state is sucked into the compressor 1, compressed to turn into high-temperature high-pressure gas, and discharged. The high-temperature high-pressure gas refrigerant discharged from the compressor 1 passes through the four-way valve 2 and then is divided to flow through two flow paths. Refrigerant that is to flow through one flow path flows into the condenser bypass 16 and is reduced in pressure by the condenser bypass valve 17, and then it flows out of the condenser bypass 16. Divided high-temperature high-pressure gas refrigerant that is to flow through the other flow path flows into the condenser 3. The high-temperature high-pressure gas refrigerant having flowed into the condenser 3 transfers heat to water serving as a medium to be subjected to heat exchange to turn into high-pressure liquid refrigerant. A flow of the high-temperature high-pressure gas refrigerant having flowed out of the condenser bypass 16 and a flow of the high-pressure liquid refrigerant having flowed out of the condenser 3 combine to form a flow of high-pressure high-quality two-phase refrigerant, and the flow flows into the suction bypass 8. The two-phase refrigerant having flowed into the suction bypass 8 is reduced in pressure and expanded by the suction bypass valve 9 to turn into low-temperature low-pressure refrigerant, and the low-temperature low-pressure refrigerant is sucked into the compressor 1 again via the accumulator 15.

[0127] Note that, since the main expansion valve 4 is substantially closed during the negative pressure prevention operation, little low-pressure two-phase refrigerant flows into the evaporator 5, and evaporation of refrigerant caused by heat exchange with outdoor air does not occur.

[0128] As described above, in Modification 2 of the refrigeration cycle apparatus according to Embodiment 6, the accumulator 15 is provided on the suction side of the compressor 1, thereby enabling excess refrigerant to be stored in the accumulator 15 during a negative pressure prevention operation in which excess refrigerant is caused. This prevents an operation in which liquid flows back to the suction side of the compressor 1, thereby enabling a highly reliable negative pressure prevention operation to continue.

[0129] In Embodiments and Modifications described above, as refrigerant, a single refrigerant of HFO-1234yf, a single refrigerant of HFO-1234ze, or a refrigerant mixture of HFO-1234yf or HFO-1234ze and R32 is used. Note that refrigerant may be any refrigerant that has a higher boiling point than R407C. Furthermore, it is desirable that refrigerant be refrigerant whose global warming potential is lower than that of R407C.

[0130] In each Embodiment described above, the case where the refrigeration cycle apparatus is used for a heat pump water heater is described, whereas the refrigeration cycle apparatus can also be used for an air-conditioning apparatus, for example.

Reference Signs List

[0131] 1 compressor 2 four-way valve 3 condenser 4 main expansion valve 5 evaporator 6 discharged gas bypass 7 discharged gas bypass valve 8 suction bypass 9 suction bypass valve 10 two-way valve 11 ejector 11 a nozzle 11b expansion section 11c diffuser 11d refrigerant suction section 12 suction pipe 13 receiver 13a receiver 14 check valve 15 accumulator 16 condenser bypass 17 condenser bypass valve 20 controller 20A negative pressure prevention control unit 20B superheat degree control unit 20a negative pressure prevention control unit 20b superheat degree control unit 21 compressor suction pressure sensor 22 compressor suction temperature sensor 30 main circuit 40 bypass 41 bypass

Claims

1. A refrigeration cycle apparatus comprising:

a main circuit in which a compressor, a condenser, a main expansion valve, and an evaporator are connected in a circle, the main circuit (30) being configured to circulate refrigerant having a higher boiling point than R407C therethrough;
a bypass configured to combine a flow of part of refrigerant discharged from the compressor and a flow of refrigerant flowing out of the condenser into a combined flow, and allowing the combined flow to flow into a suction side of the compressor;
a negative pressure regulating valve configured to regulate a flow rate in the bypass; and
a negative pressure prevention control unit configured to perform a negative pressure prevention operation of controlling the negative pressure regulating valve to prevent a suction pressure of the compressor from becoming negative.

2. The refrigeration cycle apparatus of claim 1, wherein the bypass includes
a discharged gas bypass configured to bypass part of refrigerant discharged from the compressor to a suction side, and a suction bypass configured to combine a flow of refrigerant flowing out of the condenser into a flow in the discharged gas bypass, and allowing the flow to flow into the suction side of the compressor, and
wherein the negative pressure regulating valve is a discharged gas bypass valve configured to regulate a flow rate in the discharged gas bypass.

3. The refrigeration cycle apparatus of claim 2, further comprising a pressure sensor configured to detect a suction pressure of the compressor,
wherein, when the suction pressure detected by the pressure sensor is below a first setting value set in advance, the negative pressure prevention control unit is configured to start the negative pressure prevention operation to control the discharged gas bypass valve.

4. The refrigeration cycle apparatus of claim 2 or 3, wherein, during the negative pressure prevention operation, the negative pressure prevention control unit is configured to close the main expansion valve and also regulate an opening degree of the discharged gas bypass valve so that the suction pressure becomes a second setting value set in advance.

5. The refrigeration cycle apparatus of any one of claims 2 to 4, further comprising a suction bypass valve configured to regulate a flow rate in the suction bypass to control a degree of superheat of gas to be sucked into the compressor.

6. The refrigeration cycle apparatus of claim 5, further comprising a superheat degree control unit configured to regulate an opening degree of the suction bypass valve so that a degree of superheat of gas to be sucked into the compressor becomes a third setting value set in advance.

7. The refrigeration cycle apparatus of any one of claims 1 to 6, wherein the main circuit further includes a four-way valve configured to switch between directions in which refrigerant discharged from the compressor flows.

8. The refrigeration cycle apparatus of claim 7, further comprising a two-way valve provided between the four-way valve and the evaporator.

9. The refrigeration cycle apparatus of claim 8, wherein the negative pressure prevention control unit is configured to close the two-way valve during the negative pressure prevention operation.

10. The refrigeration cycle apparatus of claim 7, further comprising:

in the bypass, an ejector provided in a discharged gas bypass configured to bypass part of refrigerant discharged from the compressor to the suction side; and
a suction circuit configured to allow a suction section of the ejector to suck refrigerant between the evaporator and the four-way valve.

11. The refrigeration cycle apparatus of any one of claims 1 to 9, further comprising a receiver provided on an outlet side of the condenser.

12. The refrigeration cycle apparatus of any one of claims 1 to 9, further comprising a receiver provided in parallel with the main circuit on an outlet side of the condenser.

13. The refrigeration cycle apparatus of any one of claims 1 to 9, further comprising an accumulator provided on the suction side of the compressor.

14. The refrigeration cycle apparatus of claim 1, wherein the bypass includes
a condenser bypass configured to bypass part of refrigerant discharged from the compressor to an outlet side of the condenser, and a suction bypass configured to combine flows of refrigerant flowing out of the condenser bypass and the condenser into a combined flow to bypass the combined flow to the suction side of the compressor, and
wherein the negative pressure regulating valve is a suction bypass valve configured to regulate a flow rate in the suction bypass.

15. The refrigeration cycle apparatus of claim 14, further comprising a pressure sensor configured to detect a suction pressure of the compressor,
wherein, when the suction pressure detected by the pressure sensor is below a first setting value set in advance, the negative pressure prevention control unit is configured to start the negative pressure prevention operation to control the suction bypass valve.

16. The refrigeration cycle apparatus of claim 14 or 15, wherein, during the negative pressure prevention operation, the negative pressure prevention control unit is configured to close the main expansion valve and also regulate an opening degree of the suction bypass valve so that the suction pressure becomes a second setting value set in advance.

17. The refrigeration cycle apparatus of any one of claims 14 to 16, further comprising a condenser bypass valve configured to regulate a flow rate in the condenser bypass to control a degree of superheat of gas to be sucked into the compressor.

18. The refrigeration cycle apparatus of claim 17, further comprising a superheat degree control unit configured to regulate an opening degree of the condenser bypass valve so that a degree of superheat of gas to be sucked into the compressor becomes a third setting value set in advance.

19. The refrigeration cycle apparatus of any one of claims 14 to 18, wherein the main circuit further includes a four-way valve configured to switch between directions in which refrigerant discharged from the compressor flows.

20. The refrigeration cycle apparatus of any one of claims 14 to 19, further comprising a receiver provided on the outlet side of the condenser.

21. The refrigeration cycle apparatus of any one of claims 14 to 19, further comprising a receiver provided in parallel with the main circuit on the outlet side of the condenser.

22. The refrigeration cycle apparatus of any one of claims 14 to 19, further comprising an accumulator provided on the suction side of the compressor.

23. The refrigeration cycle apparatus of any one of claims 1 to 22, wherein the refrigerant is any of a single refrigerant of HFO-1234yf, a single refrigerant of HFO-1234ze, and a refrigerant mixture containing HFO-1234yf or HFO-1234ze.

FIG. 1

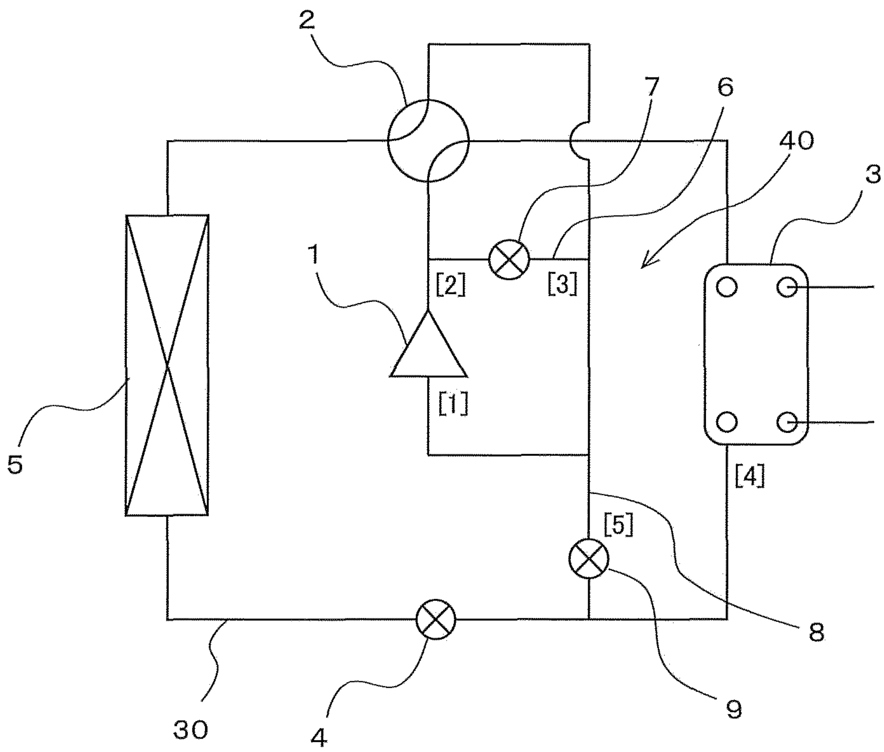

2
7
6
40
3
1
[2]
[3]
[1]
5
[4]
[5]
8
9
30
4

FIG. 2

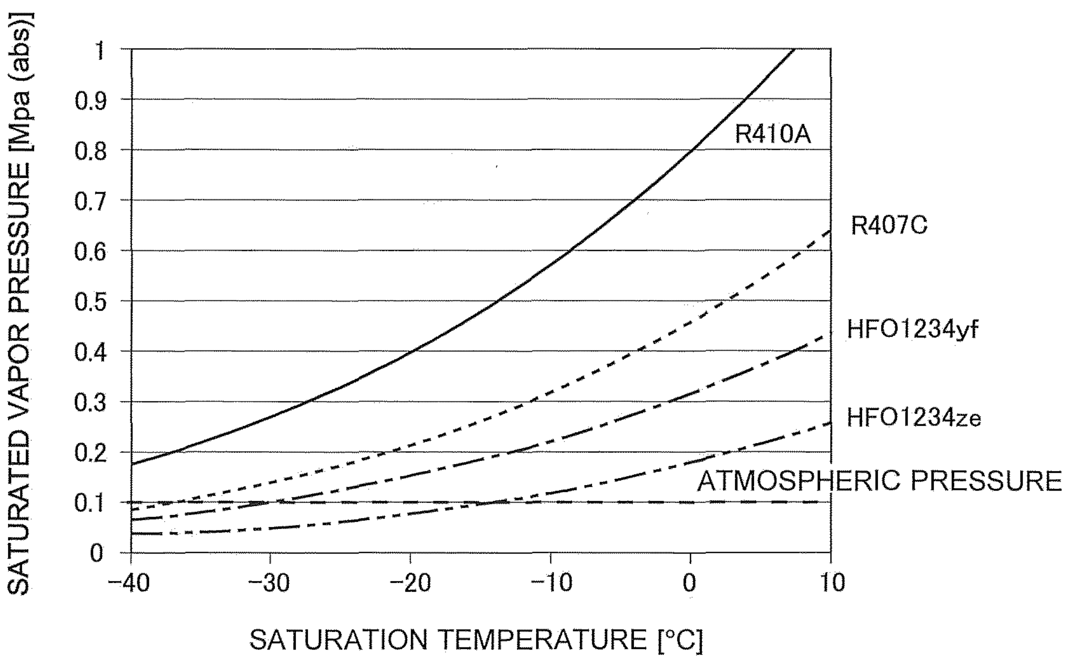

SATURATED VAPOR PRESSURE [Mpa (abs)]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
R410A
R407C
HFO1234yf
HFO1234ze
ATMOSPHERIC PRESSURE
−40
−30
−20
−10
0
10
SATURATION TEMPERATURE [°C]

FIG. 3

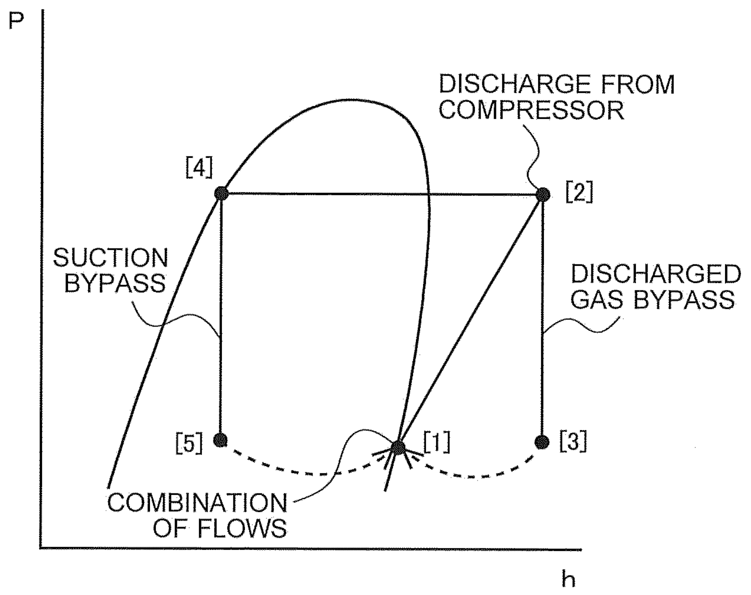

P
DISCHARGE FROM COMPRESSOR
[4]
[2]
SUCTION BYPASS
DISCHARGED GAS BYPASS
[5]
[1]
[3]
COMBINATION OF FLOWS
h

FIG. 4

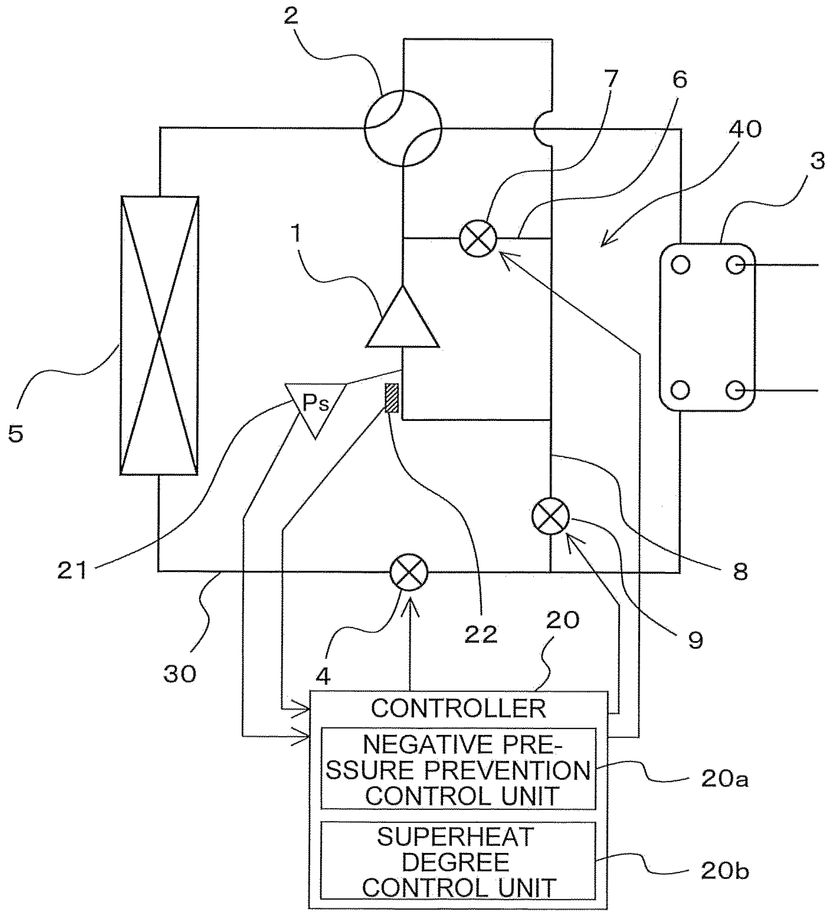
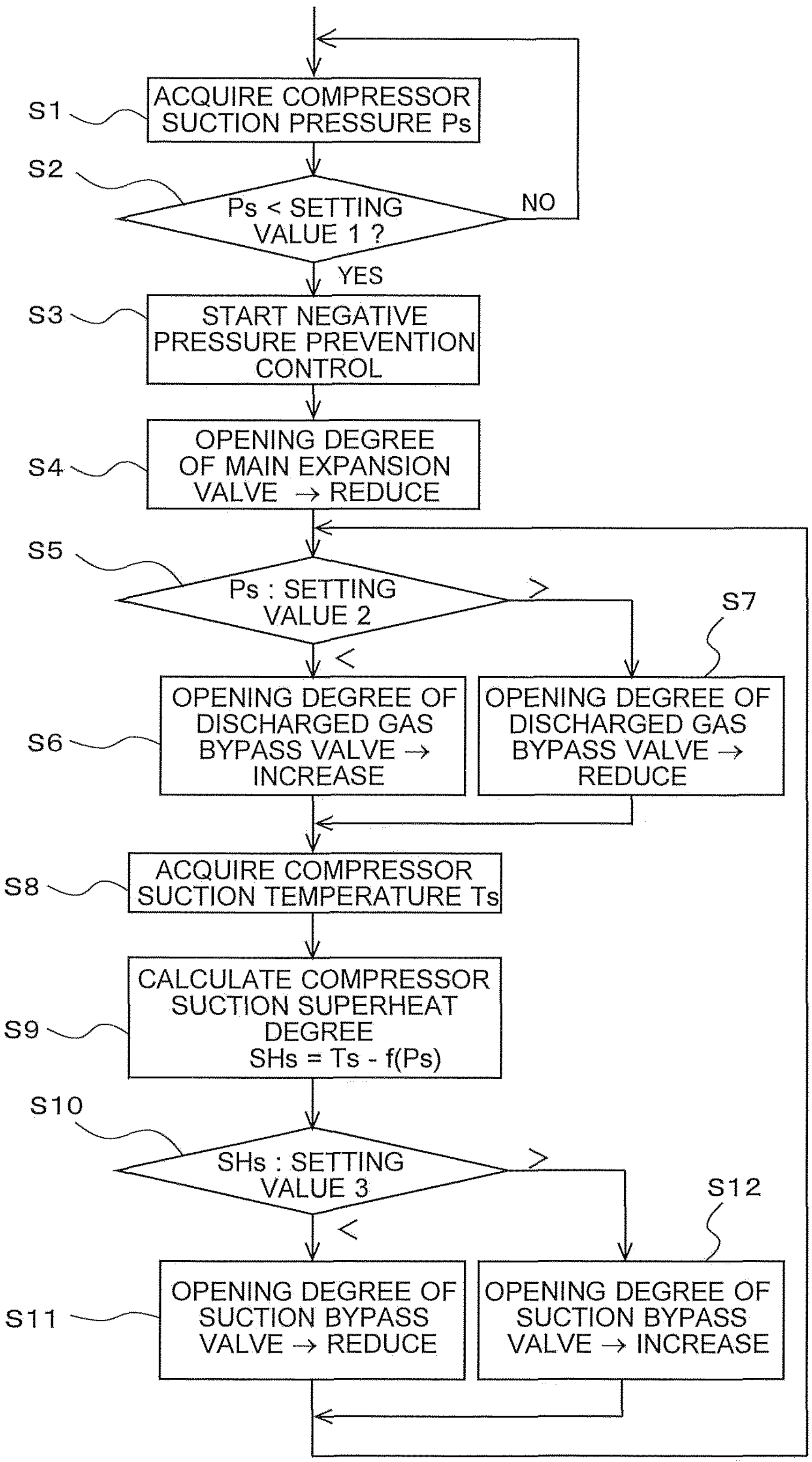

2
7
6
40
3
1
5
Ps
21
8
9
30
4
22
20
CONTROLLER
NEGATIVE PRESSURE PREVENTION CONTROL UNIT
20a
SUPERHEAT DEGREE CONTROL UNIT
20b

FIG. 5



S1
ACQUIRE COMPRESSOR SUCTION PRESSURE Ps
S2
Ps < SETTING VALUE 1 ?
NO
YES
S3
START NEGATIVE PRESSURE PREVENTION CONTROL
S4
OPENING DEGREE OF MAIN EXPANSION VALVE → REDUCE
S5
Ps : SETTING VALUE 2
>
<
S6
OPENING DEGREE OF DISCHARGED GAS BYPASS VALVE → INCREASE
S7
OPENING DEGREE OF DISCHARGED GAS BYPASS VALVE → REDUCE
S8
ACQUIRE COMPRESSOR SUCTION TEMPERATURE Ts
S9
CALCULATE COMPRESSOR SUCTION SUPERHEAT DEGREE SHs = Ts - f(Ps)
S10
SHs : SETTING VALUE 3
>
<
S11
OPENING DEGREE OF SUCTION BYPASS VALVE → REDUCE
S12
OPENING DEGREE OF SUCTION BYPASS VALVE → INCREASE

FIG. 6

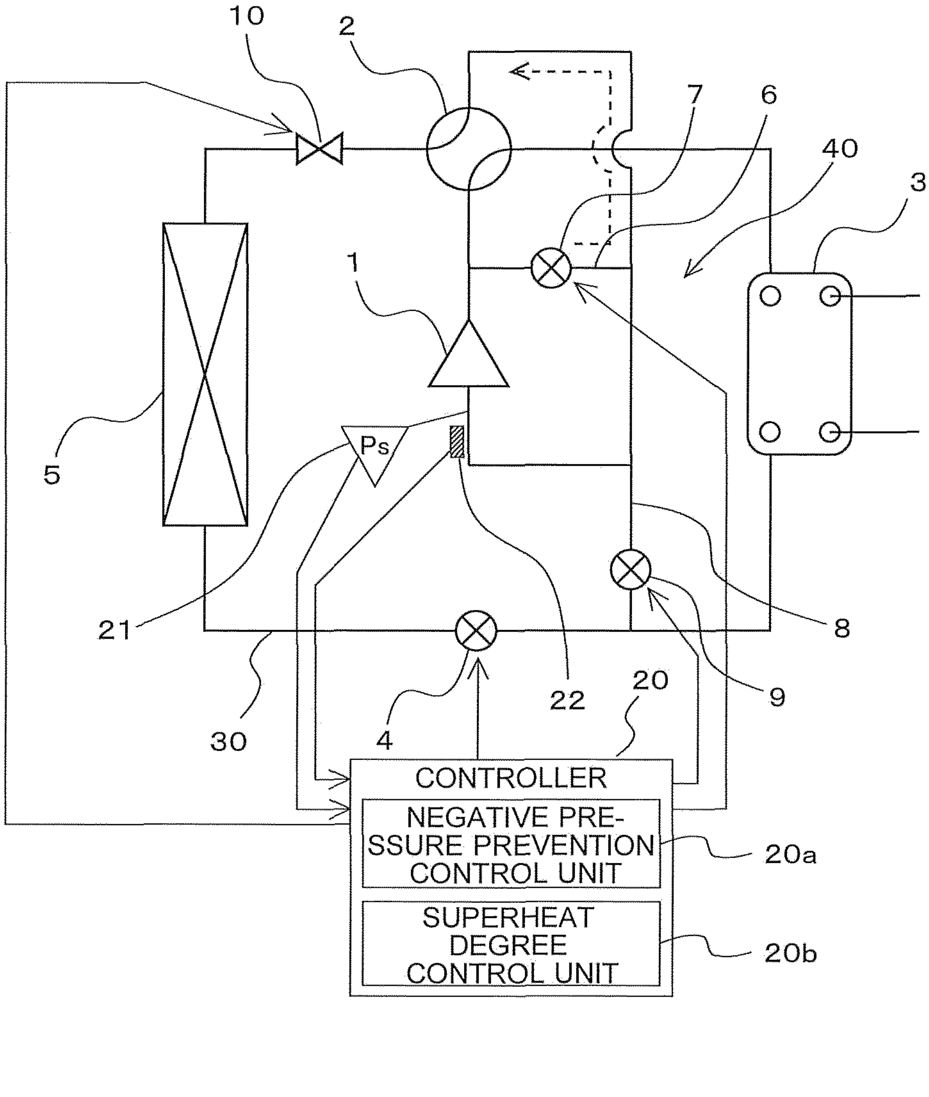

10
2
7
6
40
3
1
5
Ps
21
22
8
9
30
4
20
CONTROLLER
NEGATIVE PRE-
SSURE PREVENTION
CONTROL UNIT
20a
SUPERHEAT
DEGREE
CONTROL UNIT
20b

FIG. 7

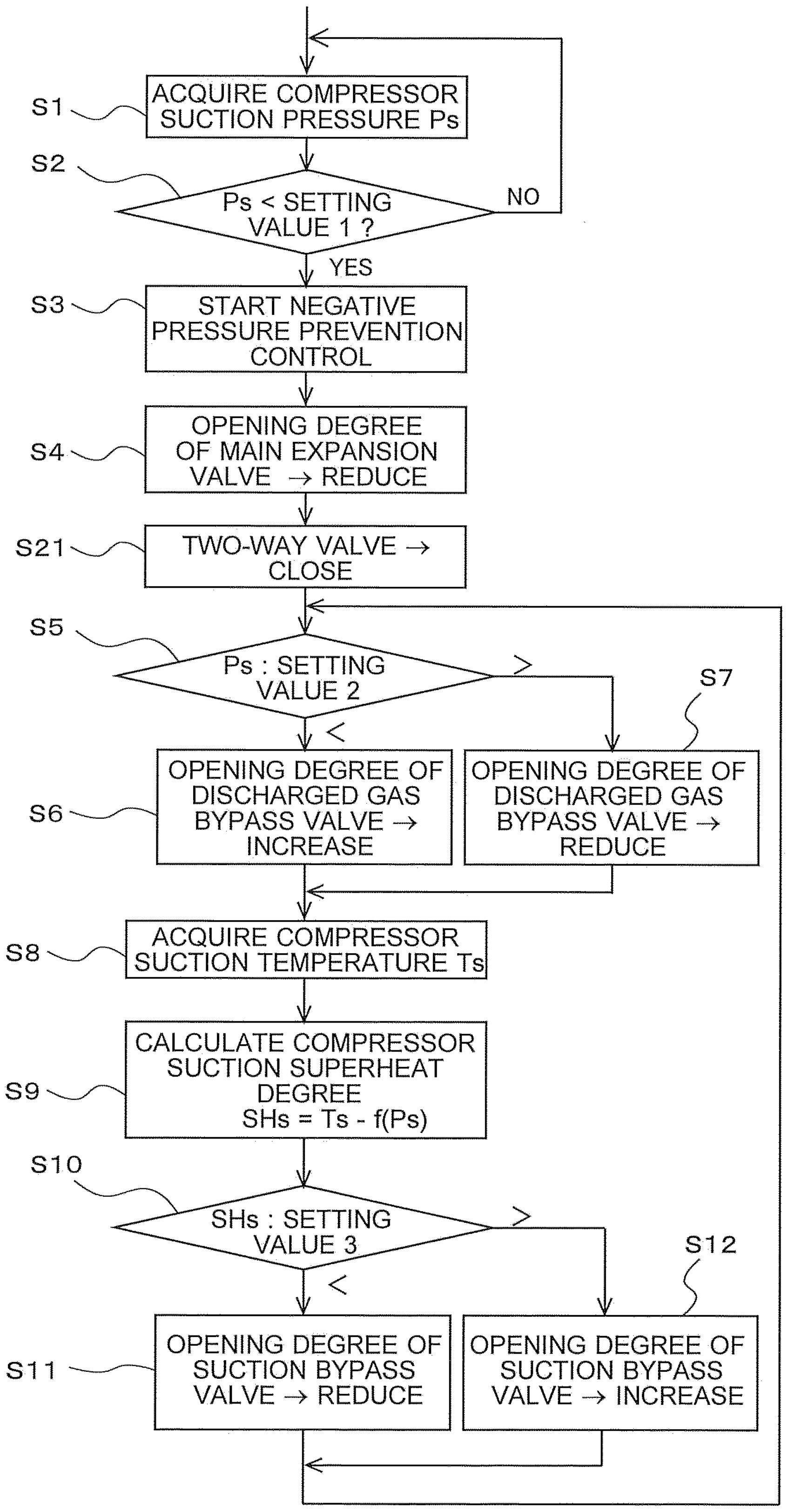

S1
ACQUIRE COMPRESSOR SUCTION PRESSURE Ps
S2
Ps < SETTING VALUE 1 ?
NO
YES
S3
START NEGATIVE PRESSURE PREVENTION CONTROL
S4
OPENING DEGREE OF MAIN EXPANSION VALVE → REDUCE
S21
TWO-WAY VALVE → CLOSE
S5
Ps : SETTING VALUE 2
>
<
S7
S6
OPENING DEGREE OF DISCHARGED GAS BYPASS VALVE → INCREASE
OPENING DEGREE OF DISCHARGED GAS BYPASS VALVE → REDUCE
S8
ACQUIRE COMPRESSOR SUCTION TEMPERATURE Ts
S9
CALCULATE COMPRESSOR SUCTION SUPERHEAT DEGREE SHs = Ts - f(Ps)
S10
SHs : SETTING VALUE 3
>
<
S12
S11
OPENING DEGREE OF SUCTION BYPASS VALVE → REDUCE
OPENING DEGREE OF SUCTION BYPASS VALVE → INCREASE

FIG. 8

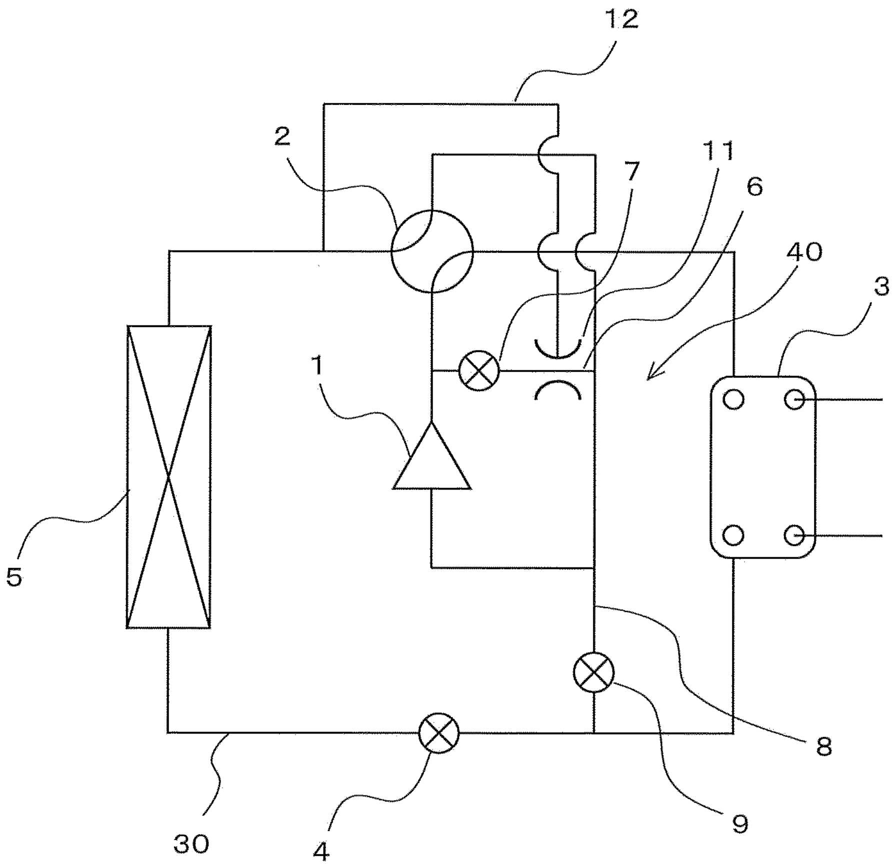

12
2
7
11
6
40
3
1
5
8
9
30
4

FIG. 9

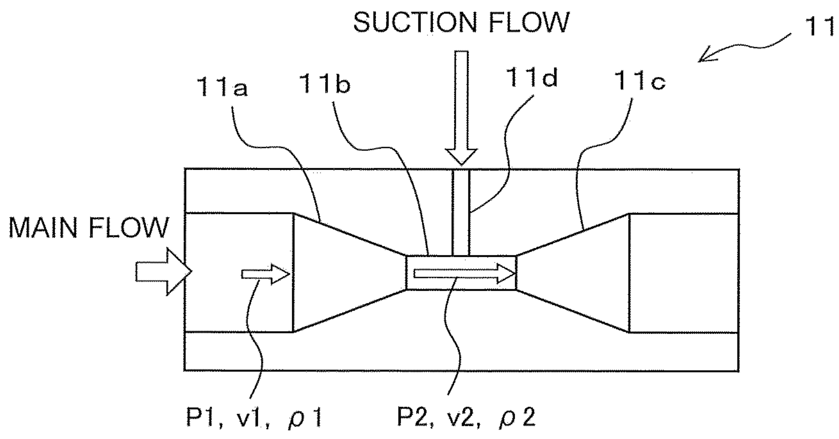

SUCTION FLOW
11
11a
11b
11d
11c
MAIN FLOW
P1, v1, ρ1
P2, v2, ρ2

FIG. 10

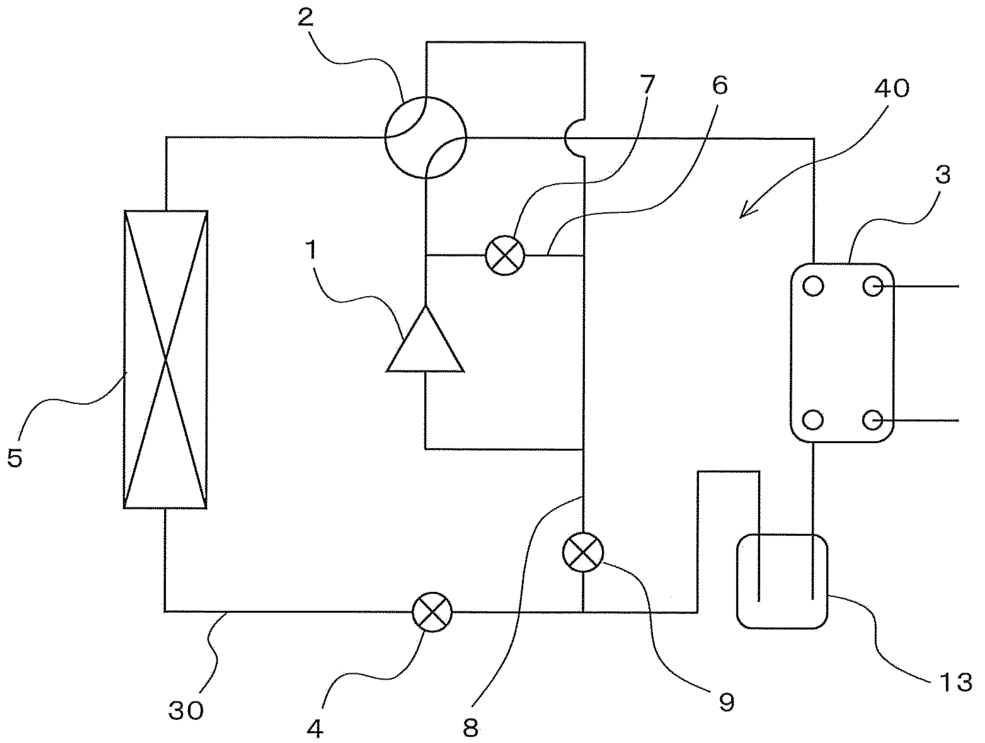


FIG. 11

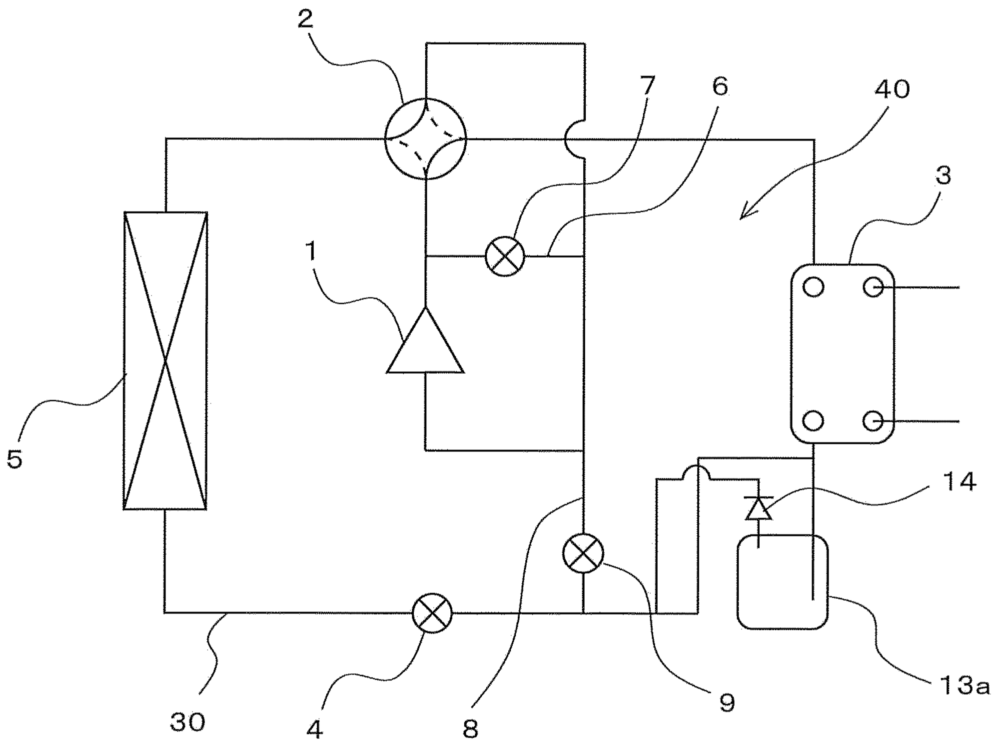


FIG. 12

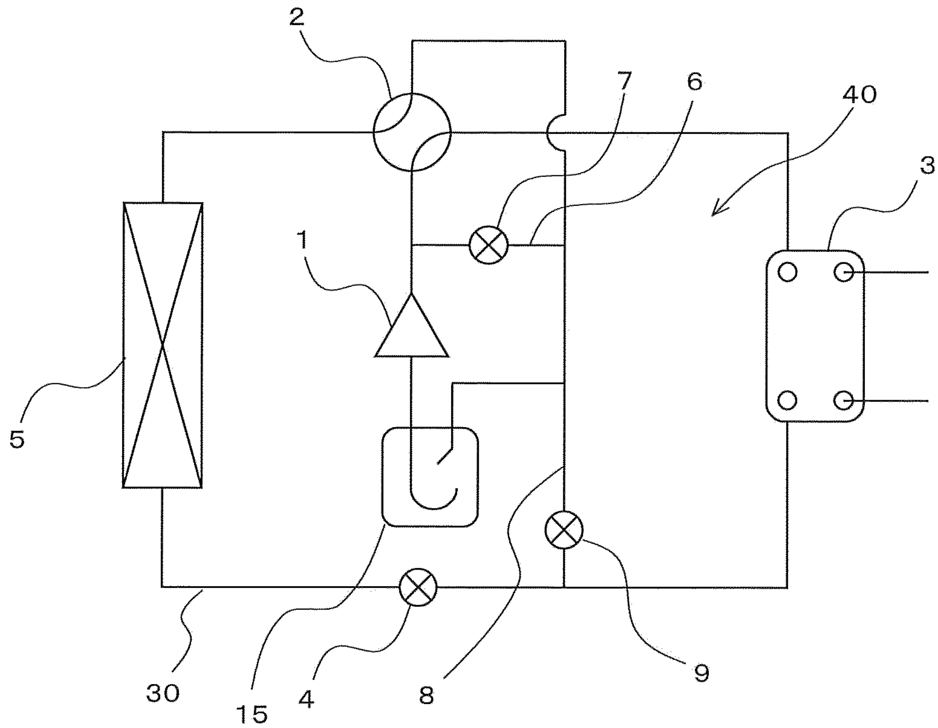


FIG. 13

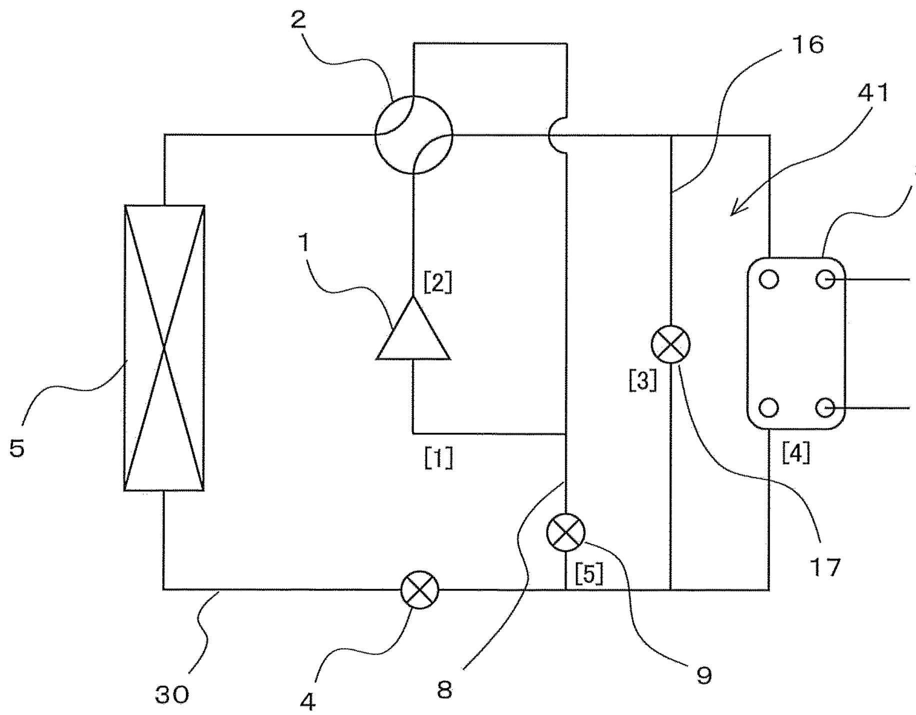


FIG. 14

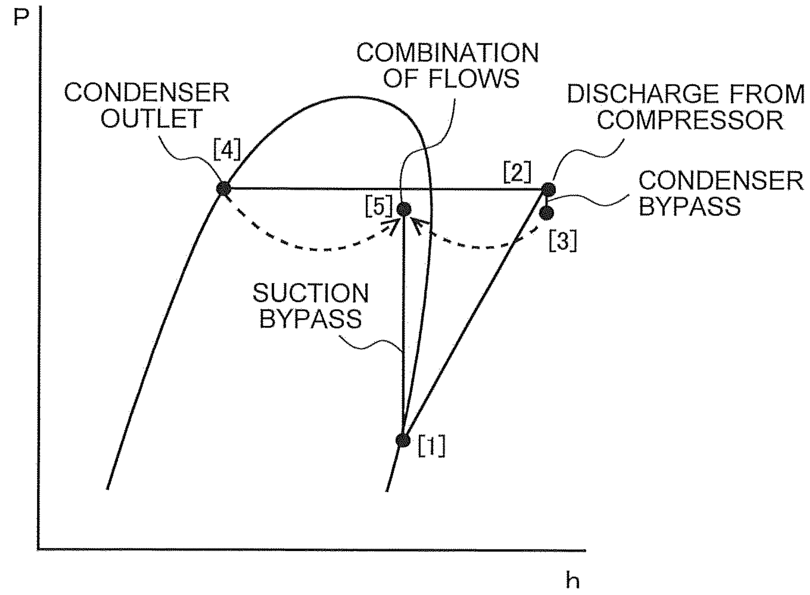

P
h
CONDENSER OUTLET
COMBINATION OF FLOWS
DISCHARGE FROM COMPRESSOR
CONDENSER BYPASS
SUCTION BYPASS
[1]
[2]
[3]
[4]
[5]

FIG. 15

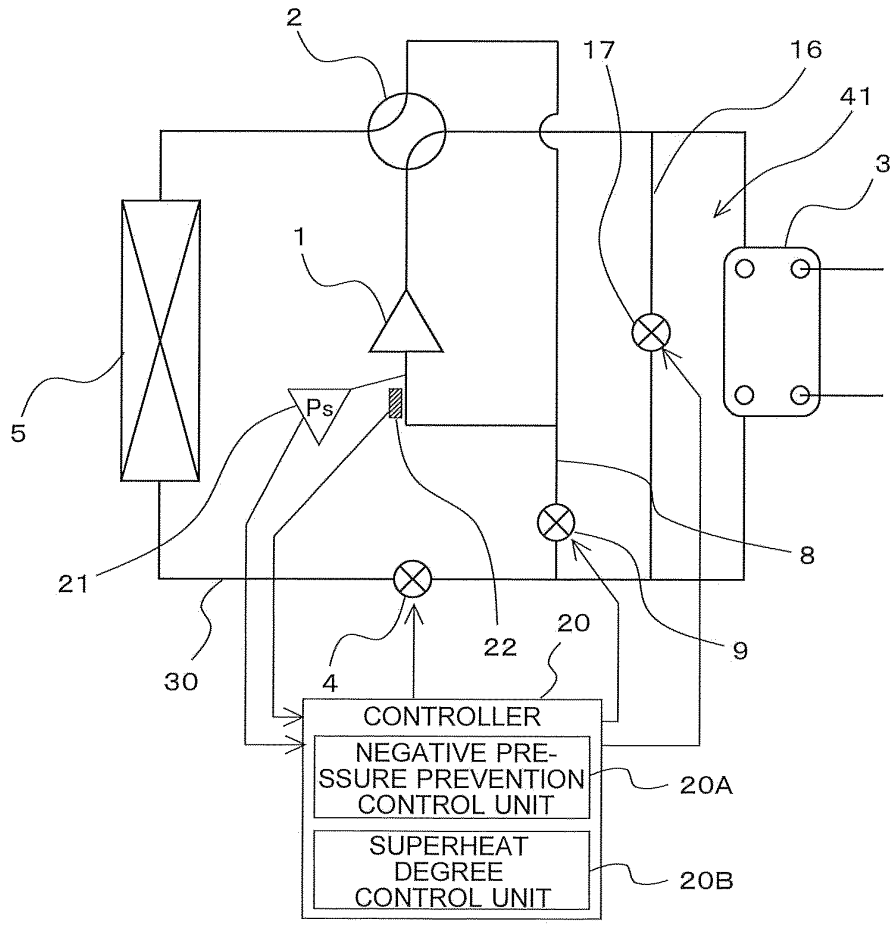

2
17
16
41
3
1
5
Ps
21
22
8
9
30
4
20
CONTROLLER
NEGATIVE PRESSURE PREVENTION CONTROL UNIT
20A
SUPERHEAT DEGREE CONTROL UNIT
20B

FIG. 16

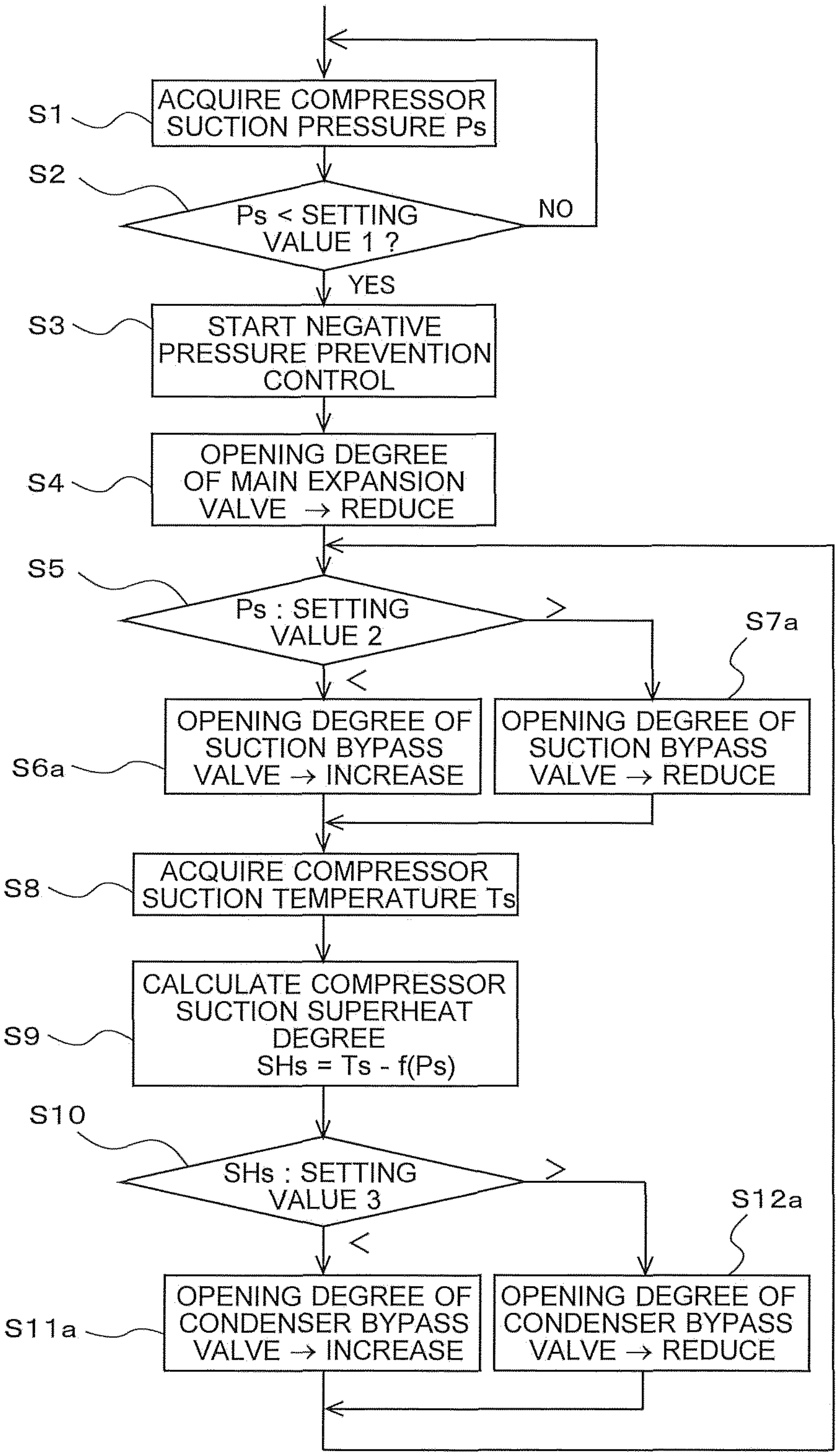

S1
ACQUIRE COMPRESSOR SUCTION PRESSURE Ps
S2
Ps < SETTING VALUE 1 ?
NO
YES
S3
START NEGATIVE PRESSURE PREVENTION CONTROL
S4
OPENING DEGREE OF MAIN EXPANSION VALVE → REDUCE
S5
Ps : SETTING VALUE 2
>
<
S7a
S6a
OPENING DEGREE OF SUCTION BYPASS VALVE → INCREASE
OPENING DEGREE OF SUCTION BYPASS VALVE → REDUCE
S8
ACQUIRE COMPRESSOR SUCTION TEMPERATURE Ts
S9
CALCULATE COMPRESSOR SUCTION SUPERHEAT DEGREE SHs = Ts - f(Ps)
S10
SHs : SETTING VALUE 3
>
<
S12a
S11a
OPENING DEGREE OF CONDENSER BYPASS VALVE → INCREASE
OPENING DEGREE OF CONDENSER BYPASS VALVE → REDUCE

FIG. 17

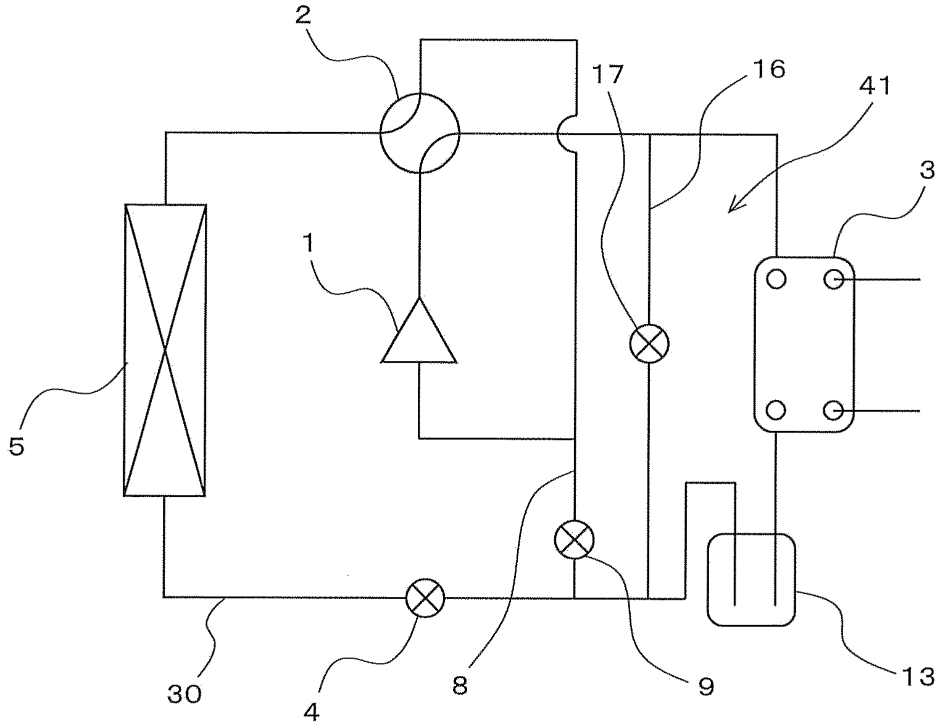


FIG. 18

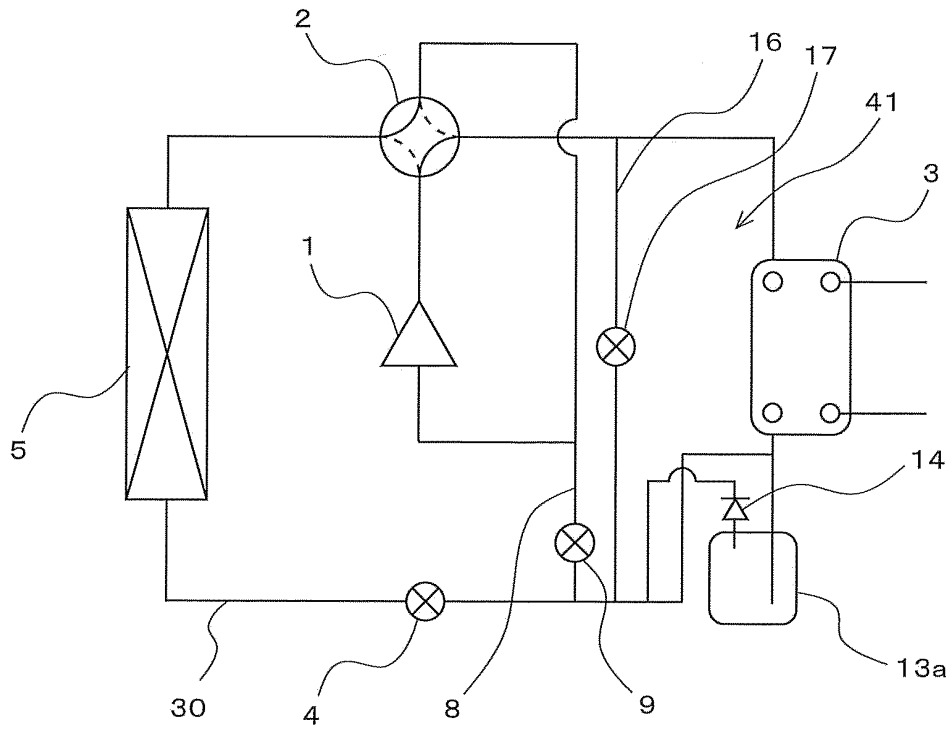
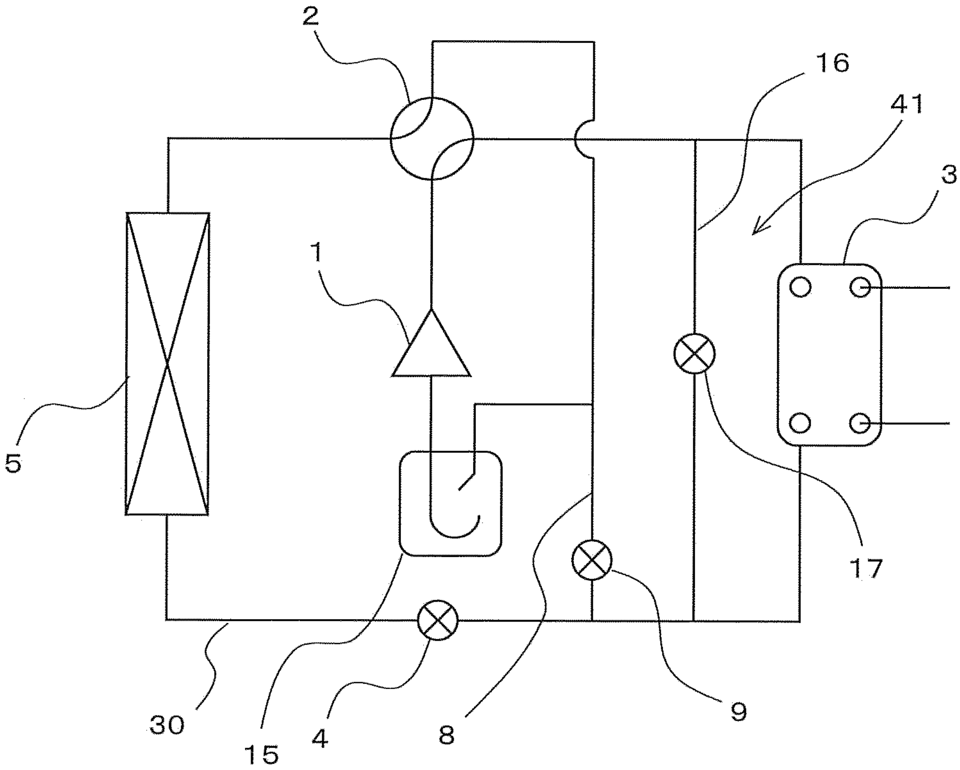


FIG. 19



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/051068

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(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)
F25B1/00

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	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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 2001-280669 A (Mitsubishi Electric Corp.), 10 October 2001 (10.10.2001), claim 1; paragraphs [0014] to [0019]; fig. 1 (Family: none)	1-3,5-8, 10-13,23
Y	WO 2014/112615 A1 (Toshiba Carrier Corp.), 24 July 2014 (24.07.2014), paragraph [0049]; fig. 1 (Family: none)	1-3,5-8, 10-13,23
Y	JP 2009-41845 A (Panasonic Corp.), 26 February 2009 (26.02.2009), paragraphs [0013], [0019] to [0022]; fig. 1 (Family: none)	1-3,5-8, 10-13,23

☒ 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
25 March 2015 (25.03.15)	07 April 2015 (07.04.15)

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

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

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2015/051068

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 2010-7874 A (Mitsubishi Electric Corp.), 14 January 2010 (14.01.2010), paragraph [0014]; fig. 1 (Family: none)	8
Y	JP 2012-117760 A (The Tokyo Electric Power Co., Inc.), 21 June 2012 (21.06.2012), paragraph [0029]; fig. 7 (Family: none)	10
Y A	US 2006/0107671 A1 (HOSHIZAKI DENKI KABUSHIKI KAISHA), 25 May 2006 (25.05.2006), paragraphs [0017], [0019]; fig. 1 (Family: none)	11-12 20-21
Y A	EP 0703422 A2 (BOSCH-SIEMENS HAUSGERATE GMBH), 27 March 1996 (27.03.1996), column 4, line 13 to column 5, line 26; fig. 1 to 2 & EP 703421 A2 & DE 4433712 A & DE 59509398 D & TR 960219 A & TR 960241 A & ES 2159586 T & SI 703421 T	11-12 20-21
A	JP 2013-228129 A (Mitsubishi Electric Corp.), 07 November 2013 (07.11.2013), paragraphs [0010] to [0025]; fig. 1 (Family: none)	1,14-22
A	WO 2012/127834 A1 (Panasonic Corp.), 27 September 2012 (27.09.2012), paragraphs [0012] to [0018], [0031] to [0039]; fig. 4 (Family: none)	1,14-22
A	JP 2-52955 A (Nippon Telegraph and Telephone Corp.), 22 February 1990 (22.02.1990), page 3, upper right column, lines 5 to 7; page 4, lower left column, line 19 to page 5, upper left column, line 2; page 5, lower right column, line 7 to page 6, upper left column, line 5; fig. 1 (Family: none)	17-18
A	JP 2012-229838 A (Taikisha Ltd.), 22 November 2012 (22.11.2012), paragraphs [0056] to [0057]; fig. 1 to 2 (Family: none)	1-13

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/051068

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 11-14165 A (Mitsubishi Heavy Industries, Ltd.), 22 January 1999 (22.01.1999), paragraph [0008]; fig. 1 (Family: none)	1-23
A	JP 2013-184592 A (Denso Corp.), 19 September 2013 (19.09.2013), paragraph [0009]; fig. 1 (Family: none)	23

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

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 2011252638 A **[0003]**