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(54) **FREEZING DEVICE**

(57) An air conditioning system (10) that is a refrigeration system that suppresses the prolongation of a defrost operation is equipped with a four-stage compressor (20), a fourth heat exchanger (44), a first heat exchanger (41), a bypass valve (28), and a control component (15). During a first cycle, the fourth heat exchanger cools refrigerant that has been discharged from a fourth compression component (24) at the uppermost stage of the four-stage compressor, and the first heat exchanger cools refrigerant that has been discharged from a first compression component (21) at the lowermost stage. During a second cycle, in which the flow of refrigerant is the opposite of what it is in the first cycle, the fourth heat exchanger and the first heat exchanger function as evaporators. The bypass valve opens and closes a bypass flow path (28a) that bypasses, from a first flow path (24b) through which the refrigerant that has been discharged from the fourth compression component flows to a second flow path (21a) through which refrigerant that becomes sucked into the first compression component flows, the refrigerant that has been discharged from the fourth compression component. The control component controls the bypass valve to open the bypass flow path

during a defrost operation that the control component performs by switching the second cycle to the first cycle.

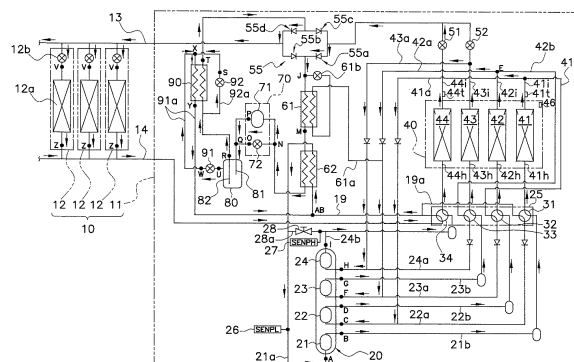


FIG. 2

**Description****TECHNICAL FIELD**

**[0001]** The present invention relates to a refrigeration system.

**BACKGROUND ART**

**[0002]** A refrigeration system equipped with a four-stage compressor, in which a first compression component, a second compression component, a third compression component, and a fourth compression component connected in series to each other are housed inside a hermetic container, and an outdoor heat exchanger, comprising a first heat exchanger, a second heat exchanger, a third heat exchanger, and a fourth heat exchanger, is known (see patent document 1 (JP-ANo. 2013-210159)).

**SUMMARY OF INVENTION**

## &lt;Technical Problem&gt;

**[0003]** In a case where this type of refrigeration system performs a defrost operation, it is necessary to connect the heat exchangers in series to each other in the refrigerant circuit. For example, in the refrigeration system of patent document 1, it is necessary to connect the first heat exchanger, the second heat exchanger, the third heat exchanger, and the fourth heat exchanger in series to each other. In this case, refrigerant is compressed in the first compression component, then travels through the first heat exchanger, and is sucked into the second compression component. The refrigerant that has been sucked into the second compression component is compressed in the second compression component, then travels through the second heat exchanger, and is sucked into the third compression component. The refrigerant that has been sucked into the third compression component is compressed in the third compression component, then travels through the third heat exchanger, and is sucked into the fourth compression component. The refrigerant that has been sucked into the fourth compression component is compressed in the fourth compression component and then travels through the fourth heat exchanger.

**[0004]** As described above, refrigerant at a high pressure and a high temperature is supplied to the fourth heat exchanger, while refrigerant at a lower pressure and a lower temperature than the refrigerant supplied to the fourth heat exchanger is supplied to the first heat exchanger. Consequently, it is difficult more for the temperature of the first heat exchanger to rise than the temperature of the fourth heat exchanger. As a result, the defrost operation becomes drawn out.

**[0005]** It is a problem of the present invention to provide a refrigeration system that suppresses a prolongation of

the defrost operation.

## &lt;Solution to Problem&gt;

**[0006]** A refrigeration system pertaining to a first aspect of the invention comprises a compression mechanism, a high-stage-corresponding heat exchanger, a low-stage-corresponding heat exchanger, a bypass valve, and a control component. The compression mechanism is configured as a result of one high-stage compression component, one or more intermediate-stage compression components, and one low-stage compression component being connected to each other in series. During a first cycle the high-stage-corresponding heat exchanger functions as a gas cooler that cools refrigerant that has been discharged from the high-stage compression component, and during a second cycle the high-stage-corresponding heat exchanger functions as an evaporator. The flow of the refrigerant in the second cycle is the opposite of the flow of the refrigerant in the first cycle. During the first cycle the low-stage-corresponding heat exchanger functions as an intercooler that cools refrigerant that has been discharged from the low-stage compression component, and during the second cycle the low-stage-corresponding heat exchanger functions as an evaporator. The bypass valve opens and closes a bypass flow path that bypasses the refrigerant that has been discharged from the high-stage compression component, from a first flow path through which the refrigerant that has been discharged from the high-stage compression component flows to a second flow path through which refrigerant that becomes sucked into the low-stage compression component flows. The control component controls the bypass valve to open the bypass flow path during a defrost operation that the control component performs by switching the second cycle to the first cycle.

**[0007]** In the refrigeration system pertaining to the first aspect of the invention, during the defrost operation the control component controls the bypass valve to open the bypass flow path. Namely, the control component bypasses, from the first flow path to the second flow path, the refrigerant that has been discharged from the high-stage compression component. Then, the temperature of the refrigerant flowing through the second flow path rises, so the low-stage-corresponding heat exchanger can be warmed in a shorter amount of time. As a result, a prolongation of the defrost operation can be suppressed.

**[0008]** In a refrigeration system pertaining to a second aspect of the invention, at an initial stage of the defrost operation the control component causes the bypass valve to maintain a state in which the bypass flow path is closed, and after the initial stage the control component causes the bypass valve to open the bypass flow path.

**[0009]** In the refrigeration system pertaining to the second aspect of the invention, at the initial stage of the defrost operation the control component causes the bypass valve to maintain a state in which the bypass flow

path is closed. Thus, the refrigerant that has been discharged from the high-stage compression component is supplied to the high-stage-corresponding heat exchanger without being bypassed to the bypass flow path. Consequently, the high-stage-corresponding heat exchanger can be intensively warmed. Thereafter, the control component causes the bypass valve to open the bypass flow path, so the low-stage-corresponding heat exchanger can be warmed after the high-stage-corresponding heat exchanger.

**[0010]** In a refrigeration system pertaining to a third aspect of the invention, when switching from one to the other of the first cycle and the second cycle, the control component causes the bypass valve to temporarily open the bypass flow path in order to equalize the pressure in a refrigerant circuit configured as a result of the compression mechanism, the high-stage-corresponding heat exchanger, and the low-stage-corresponding heat exchanger being connected.

**[0011]** In the refrigeration system pertaining to the third aspect of the invention, when switching from one to the other of the first cycle and the second cycle, the control component causes the bypass valve to open the bypass flow path in order to equalize the pressure in the refrigerant circuit. Namely, the control component utilizes the bypass valve also as a pressure equalizing valve. Because the bypass valve doubles as a pressure equalizing valve, a separate pressure equalizing valve does not need to be provided.

**[0012]** In a refrigeration system pertaining to a fourth aspect of the invention, the bypass valve is an electromagnetic valve. The control component, by causing the bypass valve to repeatedly open and close, temporarily bypasses the refrigerant that has been discharged from the high-stage compression component.

**[0013]** In the refrigeration system pertaining to the fourth aspect of the invention, a prolongation of the defrost operation can be suppressed with the simple configuration of providing the electromagnetic valve in the flow path interconnecting the first flow path and the second flow path.

**[0014]** In a refrigeration system pertaining to a fifth aspect of the invention, the bypass valve is an electric valve. The control component, by adjusting the valve opening degree of the bypass valve, temporarily bypasses the refrigerant that has been discharged from the high-stage compression component.

**[0015]** In the refrigeration system pertaining to the fifth aspect of the invention, a prolongation of the defrost operation can be suppressed with the simple configuration of providing the electric valve in the flow path interconnecting the first flow path and the second flow path. Furthermore, the refrigerant that has been discharged from the high-stage compression component is bypassed at the adjusted opening degree, so the quantity of the refrigerant that becomes bypassed can be stabilized.

#### <Advantageous Effects of Invention>

**[0016]** In the refrigeration system pertaining to the first aspect of the invention, a prolongation of the defrost operation can be suppressed.

**[0017]** In the refrigeration system pertaining to the second aspect of the invention, the low-stage-corresponding heat exchanger can be warmed after the high-stage-corresponding heat exchanger has been intensively warmed.

**[0018]** In the refrigeration system pertaining to the third aspect of the invention, a separate pressure equalizing valve does not need to be provided.

**[0019]** In the refrigeration system pertaining to the fourth aspect of the invention, a prolongation of the defrost operation can be suppressed with the simple configuration of providing the electromagnetic valve in the flow path interconnecting the first flow path and the second flow path.

**[0020]** In the refrigeration system pertaining to the fifth aspect of the invention, a prolongation of the defrost operation can be suppressed with the simple configuration of providing the electric valve in the flow path interconnecting the first flow path and the second flow path.

#### BRIEF DESCRIPTION OF DRAWINGS

**[0021]**

FIG. 1 is a general configuration diagram of an air conditioning system during a heating operation.

FIG. 2 is a general configuration diagram of the air conditioning system during a defrost operation.

FIG. 3 is a drawing describing functional blocks of the air conditioning system.

FIG. 4 is a drawing showing an example of a flowchart of processes relating to the defrost operation.

FIG. 5 is a pressure-enthalpy diagram of a refrigeration cycle during the heating operation.

FIG. 6 is a pressure-enthalpy diagram of a refrigeration cycle during the defrost operation.

FIG. 7 is a drawing showing another example of a flowchart of processes relating to the defrost operation.

#### DESCRIPTION OF EMBODIMENT

**[0022]** An embodiment of the invention will be described below. It will be noted that the following embodiment is merely a specific example and is not intended to limit the invention pertaining to the claims.

##### (1) Configuration of Air Conditioning System

**[0023]** FIG. 1 and FIG. 2 are general configuration diagrams of an air conditioning system 10 serving as an example of a refrigeration system pertaining to the embodiment of the invention. The air conditioning system

10 uses supercritical carbon dioxide refrigerant to perform a four-stage compression refrigeration cycle. The air conditioning system 10 includes an outdoor unit 11, which is a heat source unit, and plural indoor units 12, which are utilization units. The outdoor unit 11 and the plural indoor units 12 are connected to each other by communicating refrigerant pipes 13 and 14.

**[0024]** The air conditioning system 10 has a refrigerant circuit that switches between a first cycle and a second cycle. The flow of the refrigerant in the second cycle is the opposite of the flow of the refrigerant in the first cycle. In the present embodiment, the first cycle is a cooling operation cycle or a defrost operation cycle and the second cycle is a heating operation cycle.

**[0025]** FIG. 1 shows the flow of the refrigerant circulating through the refrigerant circuit during the heating operation. FIG. 2 shows the flow of the refrigerant circulating through the refrigerant circuit during the defrost operation. In FIG. 1 and FIG. 2, arrows shown along refrigerant pipes of the refrigerant circuit indicate the flow of the refrigerant. Furthermore, in FIG. 1 and FIG. 2, SENPL represents a later-described suction pressure sensor 26 and SENPH represents a later-described discharge pressure sensor 27 (see FIG. 3).

**[0026]** The refrigerant circuit of the air conditioning system 10 mainly comprises a four-stage compressor 20 serving as a compression mechanism, a composite valve 25, an outdoor heat exchanger 40, first and second outdoor electric valves 51 and 52, a bridge circuit 55, an economizer heat exchanger 61, an internal heat exchanger 62, an expansion mechanism 70, a receiver 80, a subcooling heat exchanger 90, indoor heat exchangers 12a, indoor electric valves 12b, and refrigerant pipe groups that interconnect devices and valves. Furthermore, although details will be described later, the outdoor heat exchanger 40 comprises a first heat exchanger 41 serving as a low-stage-corresponding heat exchanger, a second heat exchanger 42, a third heat exchanger 43, and a fourth heat exchanger 44 serving as a high-stage-corresponding heat exchanger.

**[0027]** The constituent elements of the refrigerant circuit will be described in detail below.

#### (1) Four-stage Compressor

**[0028]** The four-stage compressor 20 is a hermetic compressor in which a first compression component 21 serving as a low-stage compression component, a second compression component 22 and a third compression component 23 serving as intermediate-stage compression components, a fourth compression component 24 serving as a high-stage compression component, and a compressor drive motor (not shown in the drawings) are housed inside a hermetic container. The compressor drive motor drives the four compression components 21 to 24 via a drive shaft. Namely, the four-stage compressor 20 has a single-shaft four-stage compression structure where the four compression components 21 to 24 are

coupled to a single drive shaft. In the four-stage compressor 20, the first compression component 21, the second compression component 22, the third compression component 23, and the fourth compression component 24 are pipe-connected in series in this order.

**[0029]** The first compression component 21 sucks in the refrigerant from a first suction pipe 21a and discharges the refrigerant to a first discharge pipe 21b. Provided in the first suction pipe 21a is a suction pressure sensor (SENPL) 26 for detecting the suction pressure of the refrigerant flowing therein. The second compression component 22 sucks in the refrigerant from a second suction pipe 22a and discharges the refrigerant to a second discharge pipe 22b. The third compression component 23 sucks in the refrigerant from a third suction pipe 23a and discharges the refrigerant to a third discharge pipe 23b. The fourth compression component 24 sucks in the refrigerant from a fourth suction pipe 24a and discharges the refrigerant to a fourth discharge pipe 24b. Provided in the fourth discharge pipe 24b is a discharge pressure sensor (SENPH) 27 for detecting the discharge pressure of the refrigerant flowing therein.

**[0030]** The first compression component 21 is the lowermost-stage compression component and compresses refrigerant with the lowest pressure flowing through the refrigerant circuit. The second compression component 22 sucks in and compresses the refrigerant that has been compressed by the first compression component 21. The third compression component 23 sucks in and compresses the refrigerant that has been compressed by the second compression component 22. The fourth compression component 24 is the uppermost-stage compression component and sucks in and compresses the refrigerant that has been compressed by the third compression component 23. The refrigerant that has been compressed by the fourth compression component 24 and discharged to the fourth discharge pipe 24b is refrigerant with the highest pressure flowing through the refrigerant circuit.

**[0031]** It will be noted that in the present embodiment the compression components 21 to 24 are rotary-type or scroll-type positive-displacement compression components. Furthermore, the compressor drive motor is inverter-controlled by a later-described control component 15 (see FIG. 3).

**[0032]** An oil separator is provided in each of the first discharge pipe 21b, the second discharge pipe 22b, the third discharge pipe 23b, and the fourth discharge pipe 24b. The oil separators are small containers that separate lubricating oil included in the refrigerant circulating through the refrigerant circuit. Although illustration is omitted in FIG. 1 and FIG. 2, oil return tubes including capillary tubes extend from the lower portions of the oil separators toward the suction pipes 21a to 24a and return to the four-stage compressor 20 the oil separated from the refrigerant.

**[0033]** Furthermore, a check valve that stops the refrigerant from flowing toward a first switching mechanism 31 is provided in the second suction pipe 22a, a check

valve that stops the refrigerant from flowing toward a second switching mechanism 32 is provided in the third suction pipe 23a, and a check valve that stops the refrigerant from flowing toward a third switching mechanism 33 is provided in the fourth suction pipe 24a.

#### (1-2) Composite Valve

**[0034]** The composite valve 25 switches the direction of the flow of the refrigerant in the refrigerant circuit to switch between the first cycle and the second cycle. The composite valve 25 is configured by the first switching mechanism 31, the second switching mechanism 32, the third switching mechanism 33, and a fourth switching mechanism 34. The first switching mechanism 31, the second switching mechanism 32, the third switching mechanism 33, and the fourth switching mechanism 34 are each four-port switching valves.

**[0035]** The four ports of the first switching mechanism 31 are connected to the first discharge pipe 21b, the second suction pipe 22a, a high-temperature-side pipe 41h of the first heat exchanger 41, and a branch pipe 19a of a low-pressure refrigerant pipe 19. The low-pressure refrigerant pipe 19 is a refrigerant pipe in which low-pressure gas refrigerant inside the outdoor unit 11 flows, and the low-pressure refrigerant pipe 19 sends the refrigerant via the internal heat exchanger 62 to the first suction pipe 21a. The branch pipe 19a is a pipe that interconnects the first switching mechanism 31 and the low-pressure refrigerant pipe 19.

**[0036]** The four ports of the second switching mechanism 32 are connected to the second discharge pipe 22b, the third suction pipe 23a, a high-temperature-side pipe 42h of the second heat exchanger 42, and a series-connection-use first pipe 41b. The series-connection-use first pipe 41b is a pipe that interconnects the second switching mechanism 32 and a low-temperature-side pipe 41i of the first heat exchanger 41.

**[0037]** The four ports of the third switching mechanism 33 are connected to the third discharge pipe 23b, the fourth suction pipe 24a, a high-temperature-side pipe 43h of the third heat exchanger 43, and a series-connection-use second pipe 42b. The series-connection-use second pipe 42b is a pipe that interconnects the third switching mechanism 33 and a low-temperature-side pipe 42i of the second heat exchanger 42.

**[0038]** The four ports of the fourth switching mechanism 34 are connected to the fourth discharge pipe 24b, the communicating refrigerant pipe 14, a high-temperature-side pipe 44h of the fourth heat exchanger 44, and the low-pressure refrigerant pipe 19.

**[0039]** During the first cycle operation (the cooling operation or the defrost operation), the switching mechanisms 31 to 34 cause the heat exchangers 41 to 44 to function as coolers of the refrigerant that has been compressed by the four-stage compressor 20 and cause the indoor heat exchangers 12a to function as evaporators (heaters) of the refrigerant that has expanded as a result

of traveling through the expansion mechanism 70 and the indoor electric valves 12b. Furthermore, during the second cycle operation (the heating operation), the switching mechanisms 31 to 34 cause the indoor heat exchangers 12a to function as coolers (radiators) of the refrigerant that has been compressed by the four-stage compressor 20 and cause the outdoor heat exchanger 40 to function as an evaporator of the refrigerant that has expanded as a result of traveling through the expansion mechanism 70 and the outdoor electric valves 51 and 52.

**[0040]** Namely, focusing on just the four-stage compressor 20, the outdoor heat exchanger 40, the expansion mechanism 70, and the indoor heat exchangers 12a as constituent elements of the refrigerant circuit, the switching mechanisms 31 to 34 fulfill the role of switching between the first cycle, in which the refrigerant is made to circulate in the order of the four-stage compressor 20, the outdoor heat exchanger 40, the expansion mechanism 70, and the indoor heat exchangers 12a, and the second cycle, in which the refrigerant is made to circulate in the order of the four-stage compressor 20, the indoor heat exchangers 12a, the expansion mechanism 70, and the outdoor heat exchanger 40.

#### (1-3) Outdoor Heat Exchanger

**[0041]** The outdoor heat exchanger 40, as mentioned above, comprises the first heat exchanger 41, the second heat exchanger 42, the third heat exchanger 43, and the fourth heat exchanger 44. During the cooling operation or during the defrost operation, the first to third heat exchangers 41 to 43 function as intercoolers that cool the refrigerant in the middle of compression (intermediate-pressure refrigerant), and the fourth heat exchanger 44 functions as a gas cooler that cools the refrigerant with the highest pressure. The fourth heat exchanger 44 has a larger capacity than the first to third heat exchangers 41 to 43. Furthermore, during the heating operation, all the first to fourth heat exchangers 41 to 44 function as evaporators (heaters) of the low-pressure refrigerant.

**[0042]** Furthermore, a first intercooler pipe 41a, a second intercooler pipe 42a, and a third intercooler pipe 43a that are branch pipes extend from the low-temperature-side pipes 41i, 42i, and 43i of the first heat exchanger 41, the second heat exchanger 42, and the third heat exchanger 43 toward the second suction pipe 22a, the third suction pipe 23a, and the fourth suction pipe 24a. As shown in FIG. 1 and FIG. 2, a check valve is provided in each of the first intercooler pipe 41a, the second intercooler pipe 42a, and the third intercooler pipe 43a.

**[0043]** Provided in the low-temperature-side pipe 44i of the fourth heat exchanger 44 is a first temperature sensor 44t for detecting the temperature of the refrigerant traveling therethrough. Provided in the low-temperature-side pipe 41i of the first heat exchanger 41 is a second temperature sensor 41t for detecting the temperature of the refrigerant traveling therethrough. Moreover, provided in the outdoor heat exchanger 40 is an outside air

temperature sensor 46 that detects the outside air temperature.

#### (1-4) First and Second Outdoor Electric Valves

**[0044]** The first and second outdoor electric valves 51 and 52 are disposed between the outdoor heat exchanger 40 and the bridge circuit 55. Specifically, the first outdoor electric valve 51 is disposed between the fourth heat exchanger 44 and the bridge circuit 55, and the second outdoor electric valve 52 is disposed between the third heat exchanger 43 and the bridge circuit 55. During the heating operation, the refrigerant flowing from the bridge circuit 55 to the outdoor heat exchanger 40 is divided into two flows. One expands in the first outdoor electric valve 51 and flows into the fourth heat exchanger 44. The other expands in the second outdoor electric valve 52 and flows into the third heat exchanger 43.

**[0045]** During the cooling operation or during the defrost operation, the second outdoor electric valve 52 is closed and the first outdoor electric valve 51 is switched to a totally open state. During the heating operation, the first and second outdoor electric valves 51 and 52 also fulfill a role as expansion mechanisms and have their opening degrees adjusted in such a way that the quantities of the refrigerant flowing into the fourth heat exchanger 44 and the third heat exchanger 43 become proper, that is, do not flow disproportionately.

**[0046]** It will be noted that the aforementioned third intercooler pipe 43a branches from between the third heat exchanger 43 and the second outdoor electric valve 52.

#### (1-5) Bridge Circuit

**[0047]** The bridge circuit 55 is provided between the outdoor heat exchanger 40 and the indoor heat exchangers 12a. The bridge circuit 55 is connected via the economizer heat exchanger 61, the internal heat exchanger 62, and the expansion mechanism 70 to an inlet pipe 81 of the receiver 80 and is also connected via the subcooling heat exchanger 90 to an outlet pipe 82 of the receiver 80.

**[0048]** The bridge circuit 55 has four check valves 55a, 55b, 55c, and 55d. An inlet check valve 55a is a check valve that allows the refrigerant to flow only from the outdoor heat exchanger 40 toward the inlet pipe 81 of the receiver 80. An inlet check valve 55b is a check valve that allows the refrigerant to flow only from the indoor heat exchangers 12a toward the inlet pipe 81 of the receiver 80. An outlet check valve 55c is a check valve that allows the refrigerant to flow only from the outlet pipe 82 of the receiver 80 toward the outdoor heat exchanger 40. An outlet check valve 55d is a check valve that allows the refrigerant to flow only from the outlet pipe 82 of the receiver 80 toward the indoor heat exchangers 12a. Namely, the inlet check valves 55a and 55b fulfill the function of allowing the refrigerant to flow from one of the outdoor heat exchanger 40 and the indoor heat exchang-

ers 12a to the inlet pipe 81 of the receiver 80, and the outlet check valves 55c and 55d fulfill the function of allowing the refrigerant to flow from the outlet pipe 82 of the receiver 80 to the other of the outdoor heat exchanger 40 and the indoor heat exchangers 12a.

#### (1-6) Economizer Heat Exchanger

**[0049]** The economizer heat exchanger 61 causes heat exchange to take place between high-pressure refrigerant heading from the bridge circuit 55 toward the expansion mechanism 70 and the receiver 80 and intermediate-pressure refrigerant resulting from some of that high-pressure refrigerant being diverted and expanded. A fifth outdoor electric valve 61b is disposed in a pipe (an injection pipe 61a) branching from a main refrigerant pipe that allows the refrigerant to flow from the bridge circuit 55 to the expansion mechanism 70. The refrigerant that has expanded as a result of traveling through this fifth outdoor electric valve 61b and evaporated in the economizer heat exchanger 61 travels through the injection pipe 61a extending toward the second intercooler pipe 42a, flows into a section of the second intercooler pipe 42a nearer to the third suction pipe 23a than the check valve, and cools the refrigerant that is sucked into the third compression component 23 from the third suction pipe 23a.

#### (1-7) Internal Heat Exchanger

**[0050]** The internal heat exchanger 62 causes heat exchange to take place between high-pressure refrigerant heading from the bridge circuit 55 toward the expansion mechanism 70 and the receiver 80 and low-pressure gas refrigerant that travels through the expansion mechanism 70 and so forth, evaporates in the indoor heat exchangers 12a or the outdoor heat exchanger 40, and flows through the low-pressure refrigerant pipe 19. The internal heat exchanger 62 is also sometimes called a liquid-to-gas heat exchanger. The high-pressure refrigerant that has exited the bridge circuit 55 first travels through the economizer heat exchanger 61 and next travels through the internal heat exchanger 62 and heads toward the expansion mechanism 70 and the receiver 80.

#### (1-8) Expansion Mechanism

**[0051]** The expansion mechanism 70 reduces the pressure of/expands the high-pressure refrigerant that has flowed in from the bridge circuit 55 so that intermediate-pressure refrigerant in a gas-liquid two-phase state flows to the receiver 80. Namely, during the cooling operation, the expansion mechanism 70 reduces the pressure of refrigerant that is sent from the outdoor fourth heat exchanger 44 functioning as a gas cooler (radiator) of high-pressure refrigerant to the indoor heat exchangers 12a functioning as evaporators of low-pressure refrigerant. During the heating operation, the expansion

mechanism 70 reduces the pressure of refrigerant that is sent from the indoor heat exchangers 12a functioning as gas coolers (radiators) of high-pressure refrigerant to the outdoor heat exchanger 40 functioning as an evaporator of low-pressure refrigerant. The expansion mechanism 70 is configured from an expander 71 and a sixth outdoor electric valve 72. The expander 71 fulfills the role of recovering, as effective work (energy), reduction loss in the refrigerant pressure reduction process.

#### (1-9) Receiver

**[0052]** The receiver 80 separates, into liquid refrigerant and gas refrigerant, the intermediate-pressure refrigerant in a gas-liquid two-phase state that has exited the expansion mechanism 70 and entered the internal space of the receiver 80 from the inlet pipe 81. The separated gas refrigerant travels through a seventh outdoor electric valve 91 provided in a low-pressure return pipe 91a, becomes low-pressure gas-rich refrigerant, and is sent to the subcooling heat exchanger 90. The separated liquid refrigerant is sent by the outlet pipe 82 to the subcooling heat exchanger 90.

#### (1-10) Subcooling Heat Exchanger

**[0053]** The subcooling heat exchanger 90 causes heat exchange to take place between the low-pressure gas refrigerant and the intermediate-pressure liquid refrigerant that has exited from the outlet pipe 82 of the receiver 80. During the cooling operation, some of the intermediate-pressure liquid refrigerant that has exited from the outlet pipe 82 of the receiver 80 flows through a branch pipe 92a branching from between the receiver 80 and the subcooling heat exchanger 90, travels through an eighth outdoor electric valve 92, and becomes low-pressure refrigerant in a gas-liquid two-phase state. The low-pressure refrigerant that has been reduced in pressure in the eighth outdoor electric valve 92 during the cooling operation merges with the low-pressure refrigerant that has been reduced in pressure in the seventh outdoor electric valve 91, exchanges heat in the subcooling heat exchanger 90 with the intermediate-pressure liquid refrigerant heading from the outlet pipe 82 of the receiver 80 to the bridge circuit 55, travels in a superheated state from the subcooling heat exchanger 90 through the low-pressure return pipe 91a, and flows to the low-pressure refrigerant pipe 19. Meanwhile, the intermediate-pressure liquid refrigerant heading from the outlet pipe 82 of the receiver 80 to the bridge circuit 55 is robbed of its heat in the subcooling heat exchanger 90 and flows in a subcooled state to the bridge circuit 55.

**[0054]** It will be noted that during the heating operation the eighth outdoor electric valve 92 is closed so that refrigerant does not flow in the branch pipe 92a, but the intermediate-pressure liquid refrigerant that has exited from the outlet pipe 82 of the receiver 80 and the low-pressure refrigerant that has been reduced in pressure

in the seventh outdoor electric valve 91 exchange heat in the subcooling heat exchanger 90.

#### (1-11) Indoor Heat Exchangers

**[0055]** The indoor heat exchangers 12a are provided in each of the plural indoor units 12, function as evaporators of the refrigerant during the cooling operation, and function as coolers of the refrigerant during the heating operation. Water or air is passed through the indoor heat exchangers 12a as a cooling target or a heating target that exchanges heat with the refrigerant flowing inside. Here, room air from indoor fans not shown in the drawings flows in the indoor heat exchangers 12a, and conditioned air that has been cooled or heated is supplied to the rooms.

**[0056]** One end of each indoor heat exchanger 12a is connected to the indoor electric valves 12b, and the other end of each indoor heat exchanger 12a is connected to the communicating refrigerant pipe 14.

#### (1-12) Indoor Electric Valves

**[0057]** The indoor electric valves 12b are provided in each of the plural indoor units 12, adjust the quantity of the refrigerant flowing in the indoor heat exchangers 12a, and reduce the pressure of/expand the refrigerant. The indoor electric valves 12b are disposed between the communicating refrigerant pipe 13 and the indoor heat exchangers 12a.

#### (1-13) Bypass Valve

**[0058]** A bypass valve 28 is provided in a flow path interconnecting a first flow path through which the refrigerant that has been discharged from the fourth compression component 24 flows and a second flow path through which the refrigerant that becomes sucked into the first compression component 21 flows. Namely, the bypass valve 28 is provided between the fourth discharge pipe 24b and the first suction pipe 21a. The fourth discharge pipe 24b and the first suction pipe 21a are connected by a bypass pipe 28a, and the bypass valve 28 is provided in the bypass pipe 28a. The bypass valve 28 opens and closes a bypass flow path that bypasses, from the first flow path to the second flow path, the refrigerant that has been discharged from the fourth compression component 24. In the present embodiment, the bypass valve 28 is an electromagnetic valve.

#### (2) Functional Blocks of Air Conditioning System

**[0059]** FIG. 3 is a drawing describing functional blocks of the air conditioning system 10. The air conditioning system 10 is equipped with a control component 15. The control component 15 is a computer configured from a CPU, a ROM, and a RAM. The control component 15 is connected to the first temperature sensor 44t, the second

temperature sensor 41t, the composite valve 25, the bypass valve 28, the expansion mechanism 70, the outside air temperature sensor 46, the four-stage compressor 20, the suction pressure sensor 26, and the discharge pressure sensor 27. Furthermore, the control component 15 is connected to the electric valves 12b, 51, 52, 61b, 72, 91, and 92.

**[0060]** The control component 15 performs rotational speed control of the compressor drive motor of the four-stage compressor 20, switching between the heating operation cycle and the defrost operation cycle, and adjustment of the opening degrees of the electric valves on the basis of information such as room setting temperatures that have been input from the outside. In particular, in the present embodiment, although details will be described later, during the defrost operation the control component 15 controls the bypass valve 28 to open the bypass flow path.

### (3) Flowchart

**[0061]** FIG. 4 is a drawing showing an example of a flowchart of processes relating to the defrost operation. The flowchart is started in a case where a condition for starting the defrost operation is met during the heating operation. Examples of the condition for starting the defrost operation can include a case where the outside air temperature has become equal to or less than 0 degrees and the duration of the heating operation has reached a preset duration since startup or the end of an immediately prior defrost operation. In the flowchart, variable Tf represents the temperature measured by the first temperature sensor 44t and variable Ts represents the temperature measured by the second temperature sensor 41t. Furthermore, constant THf represents a preset first threshold and constant THs represents a preset second threshold. The first threshold relates to the temperature of the fourth heat exchanger 44, and more specifically is a sufficiently high temperature for removing frost sticking to the fourth heat exchanger 44. The second threshold relates to the temperature of the first heat exchanger 41, and more specifically is a sufficiently high temperature for removing frost sticking to the first heat exchanger 41. The first threshold and the second threshold are decided beforehand through a simulation and/or an experiment.

**[0062]** When the condition for starting the defrost operation is met, the control component 15 ends the heating operation. Namely, the control component 15 turns off the four-stage compressor 20 (step S101). The control component 15 causes the bypass valve 28 to temporarily open the bypass flow path in order to equalize the pressure in the refrigerant circuit (step S102).

**[0063]** The control component 15 switches the composite valve 25 (step S103). More specifically, the control component 15 switches the state of connection of the composite valve 25 from the state shown in FIG. 1 to the state shown in FIG. 2.

**[0064]** Thereafter, the control component 15 starts the

defrost operation. Namely, the control component 15 turns on the four-stage compressor 20 (step S104).

**[0065]** The control component 15 determines whether or not variable Tf is greater than constant THf (step S105). In a case where the control component 15 has determined that variable Tf is equal to or less than constant THf (NO in step S105), the control component 15 stands by as is. In this case, the fourth heat exchanger 44 has not been warmed to the sufficiently high temperature for removing frost sticking to the fourth heat exchanger 44. Consequently, the control component 15 stands by as is without causing the bypass valve 28 to open the bypass flow path. In other words, at the initial stage of the defrost operation, the control component 15 causes the bypass valve 28 to maintain the state in which the bypass flow path is closed.

**[0066]** In a case where the control component 15 has determined that variable Tf is greater than constant THf, namely, in a case where the control component 15 has determined that the fourth heat exchanger 44 has sufficiently warmed (YES in step S105), the control component 15 controls the opening and closing of the bypass valve 28 (step S106). In this way, after the initial stage of the defrost operation, the control component 15 causes the bypass valve 28 to open the bypass flow path. In the present embodiment, the control component 15, by causing the bypass valve 28 to repeatedly open and close, temporarily bypasses the refrigerant that has been discharged from the fourth compression component 24. For example, the control component 15 causes the bypass valve 28 to open and close in a stepwise manner. It will be noted that the control component 15 may also cause the bypass valve 28 to open and close just once rather than cause the bypass valve 28 to repeatedly open and close.

**[0067]** In the present embodiment, the control component 15 controls the bypass valve 28 on the basis of the output values from the suction pressure sensor 26 and the discharge pressure sensor 27. More specifically, the control component 15 receives the output values from the suction pressure sensor 26 and the discharge pressure sensor 27 and controls the opening and closing of the bypass valve 28 in such a way that the high/low pressure differential is equal to or greater than 2 MPa.

**[0068]** The control component 15 determines whether or not variable Ts is greater than constant THs (step S107). In a case where the control component 15 has determined that variable Ts is equal to or less than constant THs (NO in step S107), the control component 15 moves to step S106. In this case, the first heat exchanger 41 has not been warmed to the sufficiently high temperature for removing frost sticking to the first heat exchanger 41. Consequently, the control component 15 maintains the opening and closing control of the bypass valve 28.

**[0069]** In a case where the control component 15 has determined that variable Ts is greater than constant THs, namely, in a case where the control component 15 has determined that the first heat exchanger 41 has suffi-

ciently warmed (YES in step S107), the control component 15 causes the bypass valve 28 to close and ends the defrost operation. Namely, the control component 15 turns off the four-stage compressor 20 (step S108). The control component 15 causes the bypass valve 28 to temporarily open the bypass flow path in order to equalize the pressure in the refrigerant circuit (step S109).

**[0070]** The control component 15 switches the composite valve 25 (step S110). More specifically, the control component 15 switches the state of connection of the composite valve 25 from the state shown in FIG. 2 to the state shown in FIG. 1.

**[0071]** Thereafter, the control component 15 starts the heating operation. Namely, the control component 15 turns on the four-stage compressor 20 (step S111).

**[0072]** Thus, the control component 15 ends the series of processes relating to the defrost operation.

#### (4) Actions of Air Conditioning System

**[0073]** FIG. 5 is a pressure-enthalpy diagram (p-h diagram) of the refrigeration cycle during the heating operation. FIG. 6 is a pressure-enthalpy diagram (p-h diagram) of the refrigeration cycle during the defrost operation. More specifically, FIG. 6 is a pressure-enthalpy diagram at the initial stage of the defrost operation. In FIG. 5 and FIG. 6, the curve indicated by the upwardly convex long dashed short dashed line is the saturated liquid line and the dry saturated vapor line of the refrigerant. In FIG. 5 and FIG. 6, the points to which letters have been assigned on the refrigeration cycle represent the pressure and enthalpy of the refrigerant at the points represented by the same letters in FIG. 1 and FIG. 2. For example, the refrigerant at point B in FIG. 1 is in the pressure and enthalpy state at point B in FIG. 5. Control of each operation during the heating operation and the defrost operation of the air conditioning system 10 is performed by the control component 15. It will be noted that description of a pressure-enthalpy diagram of the refrigeration cycle during the cooling operation will be omitted.

##### (4-1) Actions During Heating Operation

**[0074]** During the heating operation, the refrigerant circulates through the refrigerant circuit in the order of the four-stage compressor 20, the indoor heat exchangers 12a, the expansion mechanism 70, and the outdoor heat exchanger 40 in the directions of the arrows along the refrigerant pipes shown in FIG. 1. The actions of the air conditioning system 10 during the heating operation will be described below with reference to FIG. 1 and FIG. 5.

**[0075]** Low-pressure gas refrigerant that is sucked into the four-stage compressor 20 from the first suction pipe 21a (point A) is compressed in the first compression component 21 and discharged to the first discharge pipe 21b (point B). The discharged refrigerant travels through the first switching mechanism 31 and flows through the second suction pipe 22a (point C).

**[0076]** The refrigerant that has been sucked into the second compression component 22 from the second suction pipe 22a is compressed and discharged to the second discharge pipe 22b (point D). The discharged refrigerant travels through the second switching mechanism 32 and flows through the third suction pipe 23a. It will be noted that intermediate-pressure refrigerant that has exchanged heat in the economizer heat exchanger 61 and flows through the injection pipe 61a (point L) also flows into the third suction pipe 23a, so the temperature of the refrigerant falls (point F).

**[0077]** The refrigerant that has been sucked into the third compression component 23 from the third suction pipe 23a is compressed and discharged to the third discharge pipe 23b (point G). The discharged refrigerant travels through the third switching mechanism 33 and flows through the fourth suction pipe 24a (point H).

**[0078]** The refrigerant that has been sucked into the fourth compression component 24 from the fourth suction pipe 24a is compressed and discharged to the fourth discharge pipe 24b (point I). The discharged high-pressure refrigerant travels through the fourth switching mechanism 34 and flows via the communicating refrigerant pipe 14 into the indoor units 12 (points Z).

**[0079]** The high-pressure refrigerant that has entered the indoor units 12 from the communicating refrigerant pipe 14 radiates heat to room air in the indoor heat exchangers 12a functioning as coolers of the refrigerant and warms the room air. The high-pressure refrigerant whose temperature has fallen due to heat exchange in the indoor heat exchangers 12a (point V) is slightly reduced in pressure when traveling through the indoor electric valves 12b, travels through the communicating refrigerant pipe 13, flows to the bridge circuit 55 of the outdoor unit 11, and heads from the inlet check valve 55b to the economizer heat exchanger 61 (point J).

**[0080]** The high-pressure refrigerant that has exited the bridge circuit 55 (point J) flows into the economizer heat exchanger 61, and some of the refrigerant is diverted and flows to the fifth outdoor electric valve 61b. The intermediate-pressure refrigerant that has been reduced in pressure/expanded in the fifth outdoor electric valve 61b and switched to a gas-liquid two-phase state (point K) exchanges heat in the economizer heat exchanger 61 with the high-pressure refrigerant heading from the bridge circuit 55 to the internal heat exchanger 62 (point J), becomes intermediate-pressure gas refrigerant (point L), and flows from the injection pipe 61a into the second intercooler pipe 42a.

**[0081]** The high-pressure refrigerant that has exchanged heat with the intermediate-pressure refrigerant exiting the fifth outdoor electric valve 61b and has exited the economizer heat exchanger 61 in a state in which its temperature has fallen (point M) next flows through the internal heat exchanger 62 and flows to the expansion mechanism 70 (point N). In the internal heat exchanger 62, the high-pressure refrigerant exchanges heat with the low-pressure refrigerant flowing from the low-pres-

sure refrigerant pipe 19 to the first suction pipe 21a of the four-stage compressor 20, so that the high-pressure refrigerant in the state at point M becomes high-pressure refrigerant in the state at point N whose temperature has fallen.

**[0082]** The high-pressure refrigerant that has exited the internal heat exchanger 62 (point N) is split into two flows, with one flowing to the expander 71 of the expansion mechanism 70 and with the other flowing to the sixth outdoor electric valve 72 of the expansion mechanism 70. The intermediate-pressure refrigerant that has been reduced in pressure/expanded in the expander 71 (point P) and the intermediate-pressure refrigerant that has been reduced in pressure/expanded in the sixth outdoor electric valve 72 (point O) merge and thereafter flow from the inlet pipe 81 into the internal space of the receiver 80 (point Q). This intermediate-pressure refrigerant in a gas-liquid two-phase state that has flowed into the receiver 80 is separated into liquid refrigerant and gas refrigerant in the internal space of the receiver 80.

**[0083]** The liquid refrigerant that has been separated in the receiver 80 (point R) travels through the outlet pipe 82 and flows as is to the subcooling heat exchanger 90, while the gas refrigerant that has been separated in the receiver 80 (point U) is reduced in pressure and becomes low-pressure refrigerant in the seventh outdoor electric valve 91 (point W) and flows to the subcooling heat exchanger 90. The intermediate-pressure refrigerant heading from the outlet pipe 82 of the receiver 80 to the subcooling heat exchanger 90 does not flow in the branch pipe 92a because the eighth outdoor electric valve 92 is closed; rather, all of it flows into the subcooling heat exchanger 90. In the subcooling heat exchanger 90, heat exchange takes place between the intermediate-pressure refrigerant flowing in from the outlet pipe 82 of the receiver 80 (point R) and the low-pressure refrigerant that has been reduced in pressure in the seventh outdoor electric valve 91 (points W, X). Due to this heat exchange, the low-pressure refrigerant flowing toward the low-pressure refrigerant pipe 19 (point X) evaporates and becomes superheated low-pressure refrigerant (point Y), and the intermediate-pressure refrigerant heading from the receiver 80 toward the bridge circuit 55 (point R) is robbed of its heat and becomes subcooled intermediate-pressure refrigerant (point T).

**[0084]** The intermediate-pressure refrigerant that has exited the subcooling heat exchanger 90 and traveled through the outlet check valve 55d of the bridge circuit 55 divides into two paths and is reduced in pressure/expanded and becomes gas-liquid two-phase low-pressure refrigerant in the first and second outdoor electric valves 51 and 52 (points AC). At this time, the opening degrees of the first and second outdoor electric valves 51 and 52 are adjusted in accordance with the amounts of pressure loss of the series-connected first to third heat exchangers 41 to 43 and the amount of pressure loss of the fourth heat exchanger 44, so that the refrigerant is kept from ending up flowing disproportionately in either one flow

path.

**[0085]** The low-pressure refrigerant that has flowed into the fourth heat exchanger 44 of the outdoor heat exchanger 40 is robbed of its heat by outside air, evaporates, and flows from the high-temperature-side pipe 44h of the fourth heat exchanger 44 via the fourth switching mechanism 34 to the low-pressure refrigerant pipe 19. Meanwhile, the low-pressure refrigerant that has flowed into the third heat exchanger 43 of the outdoor heat exchanger 40 flows successively through the second heat exchanger 42 and the first heat exchanger 41, flows via the branch pipe 19a to the low-pressure refrigerant pipe 19, and merges with the refrigerant that has exited the fourth heat exchanger 44. Specifically, the refrigerant that has exited the third heat exchanger 43 flows successively through the high-temperature-side pipe 43h of the third heat exchanger 43, the third switching mechanism 33, the series-connection-use second pipe 42b, the low-temperature-side pipe 42i of the second heat exchanger 42, the second heat exchanger 42, the high-temperature-side pipe 42h of the second heat exchanger 42, the second switching mechanism 32, the series-connection-use first pipe 41b, the low-temperature-side pipe 41i of the first heat exchanger 41, the first heat exchanger 41, the high-temperature-side pipe 41h of the first heat exchanger 41, and the first switching mechanism 31, is robbed of its heat by outside air and evaporates not only in the third heat exchanger 43 but also successively in the second heat exchanger 42 and the first heat exchanger 41, and flows from the branch pipe 19a to the low-pressure refrigerant pipe 19.

**[0086]** The low-pressure gas refrigerant that has evaporated and also been superheated in the fourth heat exchanger 44 and the series-connected first to third heat exchangers 41 to 43 merges in the low-pressure refrigerant pipe 19 on the downstream side of the outdoor heat exchanger 40 (point AD) as shown in FIG. 1, further merges (point AB) with the low-pressure refrigerant flowing in from the subcooling heat exchanger 90 (point Y), travels through the internal heat exchanger 62, and returns from the first suction pipe 21a to the four-stage compressor 20. As mentioned above, in the internal heat exchanger 62, the low-pressure refrigerant heading to the four-stage compressor 20 (point AB) and the high-pressure refrigerant heading from the bridge circuit 55 toward the receiver 80 (point M) exchange heat.

**[0087]** The air conditioning system 10 performs the heating operation cycle as a result of the refrigerant circulating through the refrigerant circuit as described above.

#### (4-2) Actions During Defrost Operation

**[0088]** During the defrost operation, the refrigerant circulates through the refrigerant circuit in the order of the four-stage compressor 20, the outdoor heat exchanger 40, the expansion mechanism 70, and the indoor heat exchangers 12a in the directions of the arrows along the

refrigerant pipes shown in FIG. 2. The actions of the air conditioning system 10 during the defrost operation will be described below with reference to FIG. 2 and FIG. 6.

**[0089]** Low-pressure gas refrigerant that is sucked into the four-stage compressor 20 from the first suction pipe 21a (point A) is compressed in the first compression component 21 and discharged to the first discharge pipe 21b (point B). The discharged refrigerant travels through the first switching mechanism 31 and is cooled in the first heat exchanger 41 functioning as an intercooler. In other words, the refrigerant thaws the frost sticking to the first outdoor heat exchanger 41. Thereafter, the refrigerant flows via the first intercooler pipe 41a into the second suction pipe 22a (point C).

**[0090]** The refrigerant that has been sucked into the second compression component 22 from the second suction pipe 22a is compressed and discharged to the second discharge pipe 22b (point D). The discharged refrigerant travels through the second switching mechanism 32 and is cooled in the second heat exchanger 42 functioning as an intercooler. In other words, the refrigerant thaws the frost sticking to the second outdoor heat exchanger 42. Thereafter, the refrigerant flows to the second intercooler pipe 42a (point E). During the defrost operation, the fifth outdoor electric valve 61b is in a totally closed state. Namely, the refrigerant does not flow in the injection pipe 61a. Consequently, the refrigerant flowing through the second intercooler pipe 42a flows as is into the third suction pipe 23a (point F).

**[0091]** The refrigerant that has been sucked into the third compression component 23 from the third suction pipe 23a is compressed and discharged to the third discharge pipe 23b (point G). The discharged refrigerant travels through the third switching mechanism 33 and is cooled in the third heat exchanger 43 functioning as an intercooler. In other words, the refrigerant thaws the frost sticking to the third outdoor heat exchanger 43. Thereafter, the refrigerant flows via the third intercooler pipe 43a into the fourth suction pipe 24a (point H).

**[0092]** The refrigerant that has been sucked into the fourth compression component 24 from the fourth suction pipe 24a is compressed and discharged to the fourth discharge pipe 24b (point I). At the initial stage of the defrost operation, the bypass flow path is closed by the bypass valve 28. Consequently, the discharged high-pressure refrigerant does not flow to the first suction pipe 21a but travels through the fourth switching mechanism 34 and is cooled in the fourth heat exchanger 44 functioning as a gas cooler. In other words, the refrigerant thaws the frost sticking to the fourth heat exchanger 44. Thereafter, the refrigerant travels through the first outdoor electric valve 51 in the totally open state and the inlet check valve 55a of the bridge circuit 55 and flows to the economizer heat exchanger 61 (point J). At the stage when the opening and closing control of the bypass valve 28 is being performed after the initial stage of the defrost operation, the bypass flow path is temporarily opened. Consequently, some of the discharged high-pressure refrigerant

flows to the first suction pipe 21a (point A). Namely, as indicated by the arrow in FIG. 6, some of the high-pressure refrigerant at point I can be guided to the first suction pipe 21a. The high-pressure refrigerant that is guided to the first suction pipe 21a is refrigerant just after being discharged to the fourth discharge pipe 24b, namely, refrigerant that has not traveled through the fourth switching mechanism 34. Consequently, the temperature of the refrigerant flowing through the first suction pipe 21a can be efficiently raised.

**[0093]** The high-pressure refrigerant that has traveled through the inlet check valve 55a of the bridge circuit 55 is not diverted to the injection pipe 61a but flows as is into the economizer heat exchanger 61 because the fifth outdoor electric valve 61b is in a totally closed state as mentioned above. The high-pressure refrigerant that has exited the economizer heat exchanger 61 (point M) next flows through the internal heat exchanger 62 and flows into the expansion mechanism 70 (point N). In the internal heat exchanger 62, the refrigerant exchanges heat with the low-pressure refrigerant flowing from the low-pressure refrigerant pipe 19 to the first suction pipe 21a of the four-stage compressor 20, so that the high-pressure refrigerant in the state at point M undergoes a reduction in temperature and becomes high-pressure refrigerant in the state at point N.

**[0094]** The high-pressure refrigerant that has exited the internal heat exchanger 62 (point N) is split into two flows, with one flowing to the expander 71 of the expansion mechanism 70 and with the other flowing to the sixth outdoor electric valve 72 of the expansion mechanism 70. The intermediate-pressure refrigerant that has been reduced in pressure/expanded in the expander 71 (point P) and the intermediate-pressure refrigerant that has been reduced in pressure/expanded in the sixth outdoor electric valve 72 (point O) merge and thereafter flow from the inlet pipe 81 into the internal space of the receiver 80 (point Q). This intermediate-pressure refrigerant in a gas-liquid two-phase state that has flowed into the receiver 80 is separated into liquid refrigerant and gas refrigerant in the internal space of the receiver 80.

**[0095]** The liquid refrigerant that has been separated in the receiver 80 (point R) travels through the outlet pipe 82 and flows as is to the subcooling heat exchanger 90, while the gas refrigerant that has been separated in the receiver 80 (point U) is reduced in pressure and becomes low-pressure refrigerant in the seventh outdoor electric valve 91 (point W) and flows to the subcooling heat exchanger 90. The intermediate-pressure refrigerant heading from the outlet pipe 82 of the receiver 80 to the subcooling heat exchanger 90 splits in front of the subcooling heat exchanger 90, with one flow traveling through the subcooling heat exchanger 90 and heading to the bridge circuit 55 and with the other flow flowing to the eighth outdoor electric valve 92 in the branch pipe 92a. The low-pressure refrigerant in the gas-liquid two-phase state that has been reduced in pressure as a result of traveling through the eighth outdoor electric valve 92 (point S)

merges (point X) with the low-pressure refrigerant that has traveled through the seventh outdoor electric valve 91 (point W) and flows via the subcooling heat exchanger 90 to the low-pressure refrigerant pipe 19. Due to heat exchange in the subcooling heat exchanger 90, the low-pressure refrigerant flowing toward the low-pressure refrigerant pipe 19 (point X) evaporates and becomes superheated low-pressure refrigerant (point Y), and the intermediate-pressure refrigerant flowing toward the bridge circuit 55 (point R) is robbed of its heat and becomes subcooled intermediate-pressure refrigerant (point T).

**[0096]** The intermediate-pressure refrigerant that has been subcooled in the subcooling heat exchanger 90 (point T) travels through the outlet check valve 55d of the bridge circuit 55 and flows to the communicating refrigerant pipe 13. The refrigerant that has entered the indoor units 12 from the communicating refrigerant pipe 13 expands when traveling through the indoor electric valves 12b, becomes gas-liquid two-phase low-pressure refrigerant (point V), and flows into the indoor heat exchangers 12a. This low-pressure refrigerant is robbed of its heat by room air in the indoor heat exchangers 12a and becomes superheated low-pressure gas refrigerant (points Z). The low-pressure refrigerant that has exited the indoor units 12 flows via the communicating refrigerant pipe 14 and the fourth switching mechanism 34 to the low-pressure refrigerant pipe 19.

**[0097]** The low-pressure refrigerant that has returned from the indoor units 12 (points Z) and the low-pressure refrigerant flowing from the subcooling heat exchanger 90 (point Y) merge in the low-pressure refrigerant pipe 19 (point AB), travel through the internal heat exchanger 62, and return from the first suction pipe 21a to the four-stage compressor 20. As described above, in the internal heat exchanger 62, the low-pressure refrigerant heading to the four-stage compressor 20 (point AB) and the high-pressure refrigerant heading from the bridge circuit 55 to the receiver 80 (point M) exchange heat.

**[0098]** The air conditioning system 10 performs the defrost operation cycle as a result of the refrigerant circulating through the refrigerant circuit as described above.

#### (5) Characteristics of Air Conditioning System

**[0099]** In the air conditioning system 10 of the present embodiment, the control component 15 controls the bypass valve 28 to open the bypass flow path during the defrost operation that the control component 15 performs by switching the second cycle to the first cycle. Namely, the control component 15 bypasses, from the first flow path through which the refrigerant that has been discharged from the fourth compression component 24 flows to the second flow path through which the refrigerant that becomes sucked into the first compression component 21 flows, the refrigerant that has been discharged from the fourth compression component 24. Then, the temperature of the refrigerant flowing through the second

flow path rises, so the first heat exchanger 41 can be warmed in a shorter amount of time. As a result, a prolongation of the defrost operation can be suppressed.

**[0100]** In the air conditioning system 10 of the present embodiment, at the initial stage of the defrost operation the control component 15 causes the bypass valve 28 to maintain a state in which the bypass flow path is closed. Thus, the refrigerant that has been discharged from the fourth compression component 24 is supplied to the fourth heat exchanger 44 without being bypassed to the bypass flow path. Consequently, the fourth heat exchanger 44 can be intensively warmed. After the initial stage the control component 15 opens the bypass flow path. Consequently, the first heat exchanger 41 can be warmed after the fourth heat exchanger 44.

**[0101]** In the air conditioning system 10 of the present embodiment, when switching from one to the other of the first cycle and the second cycle, the control component 15 causes the bypass valve 28 to temporarily open the bypass flow path in order to equalize the pressure in the refrigerant circuit. Namely, the control component 15 utilizes the bypass valve 28 also as a pressure equalizing valve. Because the bypass valve 28 doubles as a pressure equalizing valve, a separate pressure equalizing valve does not need to be provided.

**[0102]** In the air conditioning system 10 of the present embodiment, the bypass valve 28 is an electromagnetic valve. The control component 15, by causing the bypass valve 28 to repeatedly open and close, temporarily bypasses the refrigerant that has been discharged from the fourth compression component 24. A prolongation of the defrost operation can be suppressed with the simple configuration of providing the electromagnetic valve in the flow path interconnecting the first flow path and the second flow path.

#### <Example Modifications>

**[0103]** Example modifications applicable to the embodiment of the invention will be described.

#### (1) Example Modification A

**[0104]** In the above description, the control component 15 controlled the opening and closing of the bypass valve 28 (step S106) in a case where the control component 15 determined that variable Tf is greater than constant THf (YES in step S105), but a step in which the control component 15 raises the high pressure by adjusting the expansion mechanism 70 may also be provided between these steps. The control component 15 may, by closing the sixth outdoor electric valve 72, raise the high pressure to an extent that the high pressure does not rise to an extreme level, such as, for example, a range in which the high/low pressure differential does not exceed 12 MPa. At this time, the control component 15 may make the opening degree of the sixth outdoor electric valve 72 after determining that variable Tf is greater than constant THf

narrower than the opening degree of the sixth outdoor electric valve 72 at the initial stage of the defrost operation.

## (2) Example Modification B

**[0105]** In the above description, the control component 15 moved to step 106 in a case where the control component 15 determined that variable  $T_s$  is equal to or less than constant  $TH_s$  (NO in step S107), but the control component 15 may also move to step S108. Namely, the control component 15 may also simply execute the process of step S106 once regardless of the temperature measured by the second temperature sensor 41t. Thereafter, the control component 15 may end the defrost operation in a case where the control component 15 has determined that variable  $T_s$  is greater than constant  $TH_s$ .

## (3) Example Modification C

**[0106]** In the above description, an electromagnetic valve was given as an example of the bypass valve 28, but the bypass valve 28 is not limited to this. The bypass valve 28 may also be an electric valve.

**[0107]** FIG. 7 is a drawing showing another example of a flowchart of processes relating to the defrost operation. The flowchart is started in a case where a condition for starting the defrost operation is met during the heating operation. An example of the condition for starting the defrost operation has already been described. Furthermore, variable  $T_f$ , variable  $T_s$ , constant  $TH_f$ , and constant  $TH_s$  in the flowchart have also already been described.

**[0108]** The processes from step S201 to step S205 in FIG. 7 are the same as the processes from step S101 to step S105 in FIG. 4. In a case where the control component 15 has determined in step S205 that variable  $T_f$  is greater than constant  $TH_f$  (YES in step S205), the control component 15 adjusts the valve opening degree of the bypass valve 28 (step S206). The control component 15 may adjust, at the point in time when it starts the adjustment, the bypass valve 28 to a preset valve opening degree. Thereafter, the control component 15 may adjust the valve opening degree of the bypass valve 28 on the basis of the output values from the suction pressure sensor 26 and the discharge pressure sensor 27. More specifically, the control component 15 may receive the output values from the suction pressure sensor 26 and the discharge pressure sensor 27 and adjust the valve opening degree of the bypass valve 28 in such a way that the high/low pressure differential is equal to or greater than 2 MPa.

**[0109]** As described above, after the initial stage of the defrost operation the control component 15 causes the bypass valve 28 to open the bypass flow path. In this example modification, the control component 15 temporarily bypasses the refrigerant that has been discharged from the fourth compression component 24. The control component 15 in step S206 controls the valve opening

degree of the bypass valve 28 in such a way that pressure is not equalized. Specifically, the control component 15 makes the valve opening degree in step S206 narrower than the valve opening degree in step S202. It will be noted that it suffices for the process of causing the bypass valve 28 to open the bypass flow path to be performed after the end of the heating operation and at a stage somewhere during the defrost operation.

**[0110]** The processes of step S207 and step S208 in FIG. 7 are the same as the processes of step S107 and step S108 in FIG. 4. After these, the control component 15 causes the bypass valve 28 to close the bypass flow path (step S209). It will be noted that it suffices for the process of causing the bypass valve 28 to close the bypass flow path to be performed around the end of the defrost operation.

**[0111]** The processes from step S210 to step S212 in FIG. 7 are the same as the processes from step S109 to step S111 in FIG. 4.

**[0112]** Thus, the control component 15 ends the series of processes relating to the defrost operation.

**[0113]** As described above, in the air conditioning system 10 of this example modification, the bypass valve 28 is an electric valve. The control component 15, by adjusting the valve opening degree of the bypass valve 28, temporarily bypasses the refrigerant that has been discharged from the fourth compression component 24. A prolongation of the defrost operation can be suppressed with the simple configuration of providing the electric valve in the flow path interconnecting the first flow path and the second flow path. Furthermore, the refrigerant that has been discharged from the fourth compression component 24 is bypassed at the adjusted opening degree, so the quantity of the refrigerant that becomes bypassed can be stabilized.

## (4) Example Modification D

**[0114]** In the above description, the control component 15 controlled the bypass valve 28 on the basis of the output values from the suction pressure sensor 26 and the discharge pressure sensor 27, but the control component 15 may also control the bypass valve 28 on the basis of at least one of how long and the number of times the control component 15 opens and closes the bypass valve 28, which is set beforehand. In this case, the air conditioning system 10 does not need to be equipped with the suction pressure sensor 26 and the discharge pressure sensor 27. It will be noted that the at least one of how long and the number of times the control component 15 opens and closes the bypass valve 28 is decided beforehand through a simulation and/or an experiment so that the high/low pressure differential is equal to or greater than 2 MPa, for example.

**[0115]** Similarly, the control component 15 may also adjust the bypass valve 28 in accordance with a preset valve opening degree and the duration of the valve opening degree. In this case, the valve opening degree and

the duration of the valve opening degree are decided beforehand through a simulation and/or an experiment so that the high/low pressure differential is equal to or greater than 2 MPa, for example.

#### (5) Example Modification E

**[0116]** In the above description, the intermediate-stage compression component comprised the two stages of the second compression component 22 and the third compression component 23, but it may also comprise one stage of just either one. Namely, the air conditioning system 10 may also have a configuration equipped with a three-stage compressor instead of the four-stage compressor 20. The intermediate-stage compression component may also comprise three or more stages. Furthermore, in the above description, the bypass valve 28 doubled as a pressure equalizing valve, but a separate pressure equalizing valve may also be provided.

#### (6) Example Modification F

**[0117]** In the above description, the control component 15 bypassed, from the first flow path through which the refrigerant that has been discharged from the fourth compression component 24 flows to the second flow path through which the refrigerant that becomes sucked into the first compression component 21 flows, the refrigerant that has been discharged from the fourth compression component 24, but it is not invariably necessary for the flow path just after discharge and the flow path just before suction to be interconnected. Other flow paths may also be interconnected provided that the temperature of the refrigerant just before suction rises because of a bypass.

#### (7) Example Modification G

**[0118]** In the above description, the control component 15 controlled the opening and closing of the bypass valve 28 in a case where the fourth heat exchanger 44 sufficiently warmed, but the control component 15 may also control the opening and closing of the bypass valve 28 before the fourth heat exchanger 44 sufficiently warms. In this case, the control component 15 may control the opening and closing of the bypass valve 28 in order to guide to a certain extent to the fourth heat exchanger 44 the refrigerant that has been discharged from the fourth compression component 24. For example, if the bypass valve 28 is an electromagnetic valve, in the case of controlling the opening and closing of the bypass valve 28 before the fourth heat exchanger 44 sufficiently warms, the control component 15 may reduce the number of times it opens and closes the bypass valve 28, or may shorten the duration in which the bypass valve 28 is open, in comparison to the case where the control component 15 controls the opening and closing of the bypass valve 28 after the fourth heat exchanger 44 has sufficiently warmed. Furthermore, if the bypass valve 28 is an electric

valve, in the case of controlling the opening and closing of the bypass valve 28 before the fourth heat exchanger 44 sufficiently warms, the control component 15 may make the valve opening narrower in comparison to the case where the control component 15 controls the opening and closing of the bypass valve 28 after the fourth heat exchanger 44 has sufficiently warmed.

**[0119]** The invention has been described above using an embodiment, but the technical scope of the invention is not limited to the scope described in the embodiment. It will be apparent to those skilled in the art that various changes or improvements can be made to the embodiment. That embodiments to which such changes or improvements have been made are also included in the technical scope of the invention will be apparent from the claims.

**[0120]** It should be noted that the order of execution of processes such as operations, procedures, steps, and stages in devices, programs, and methods appearing in the claims, specification, and drawings can be realized in an arbitrary order unless expressions such as "before" and "preceding" are clearly indicated or in a case where the output of a previous process is used in a subsequent process. Even if an operational flow in the claims, specification, and drawings has been described using expressions such as "first" and "next" for the sake of convenience, this does not mean that the operational flow must be implemented in this order.

#### REFERENCE SIGNS LIST

##### [0121]

|    |                              |
|----|------------------------------|
| 10 | Air Conditioning System      |
| 15 | Control Component            |
| 20 | Four-stage Compressor        |
| 21 | First Compression Component  |
| 22 | Second Compression Component |
| 23 | Third Compression Component  |
| 24 | Fourth Compression Component |
| 28 | Bypass Valve                 |
| 41 | First Heat Exchanger         |
| 44 | Fourth Heat Exchanger        |

#### CITATION LIST

<Patent Literature>

**[0122]** Patent Document 1: JP-ANo. 2013-210159

#### Claims

1. A refrigeration system (10) comprising:
  - a compression mechanism (20) in which one high-stage compression component (24), one or more intermediate-stage compression com-

- ponents (22, 23), and one low-stage compression component (21) are connected to each other in series;  
 a high-stage-corresponding heat exchanger (44) which, during a first cycle, functions as a gas cooler that cools refrigerant that has been discharged from the high-stage compression component and which, during a second cycle in which the flow of the refrigerant is the opposite of the flow of the refrigerant in the first cycle, functions as an evaporator;  
 a low-stage-corresponding heat exchanger (41) which, during the first cycle, functions as an intercooler that cools refrigerant that has been discharged from the low-stage compression component and which, during the second cycle, functions as an evaporator;  
 a bypass valve (28) that opens and closes a bypass flow path (28a) that bypasses, from a first flow path (24b) through which the refrigerant that has been discharged from the high-stage compression component flows to a second flow path (21a) through which refrigerant that becomes sucked into the low-stage compression component flows, the refrigerant that has been discharged from the high-stage compression component; and  
 a control component (15) that controls the bypass valve to open the bypass flow path during a defrost operation that the control component performs by switching the second cycle to the first cycle.
2. The refrigeration system according to claim 1, wherein at an initial stage of the defrost operation the control component causes the bypass valve to maintain a state in which the bypass flow path is closed, and after the initial stage the control component causes the bypass valve to open the bypass flow path.
3. The refrigeration system according to claim 1 or claim 2, wherein when switching from one to the other of the first cycle and the second cycle, the control component causes the bypass valve to temporarily open the bypass flow path in order to equalize the pressure in a refrigerant circuit configured as a result of the compression mechanism, the high-stage-corresponding heat exchanger, and the low-stage-corresponding heat exchanger being connected.
4. The refrigeration system according to any one of claim 1 to claim 3, wherein  
 the bypass valve is an electromagnetic valve, and  
 the control component, by causing the bypass valve to repeatedly open and close, temporarily bypasses the refrigerant that has been discharged from the high-stage compression component.
5. The refrigeration system according to any one of claim 1 to claim 3, wherein  
 the bypass valve is an electric valve, and  
 the control component, by adjusting the valve opening degree of the bypass valve, temporarily bypasses the refrigerant that has been discharged from the high-stage compression component.

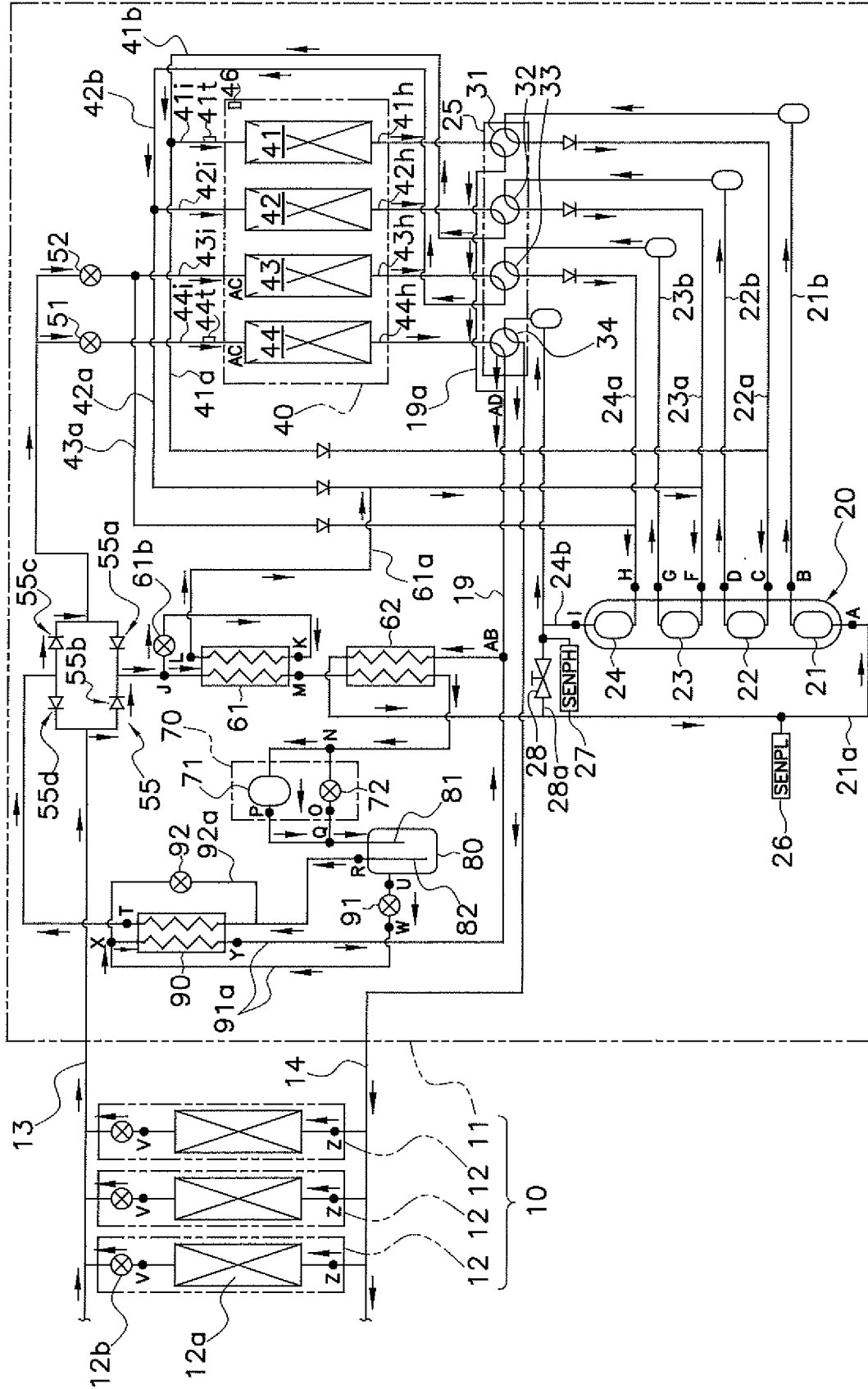


FIG. 1

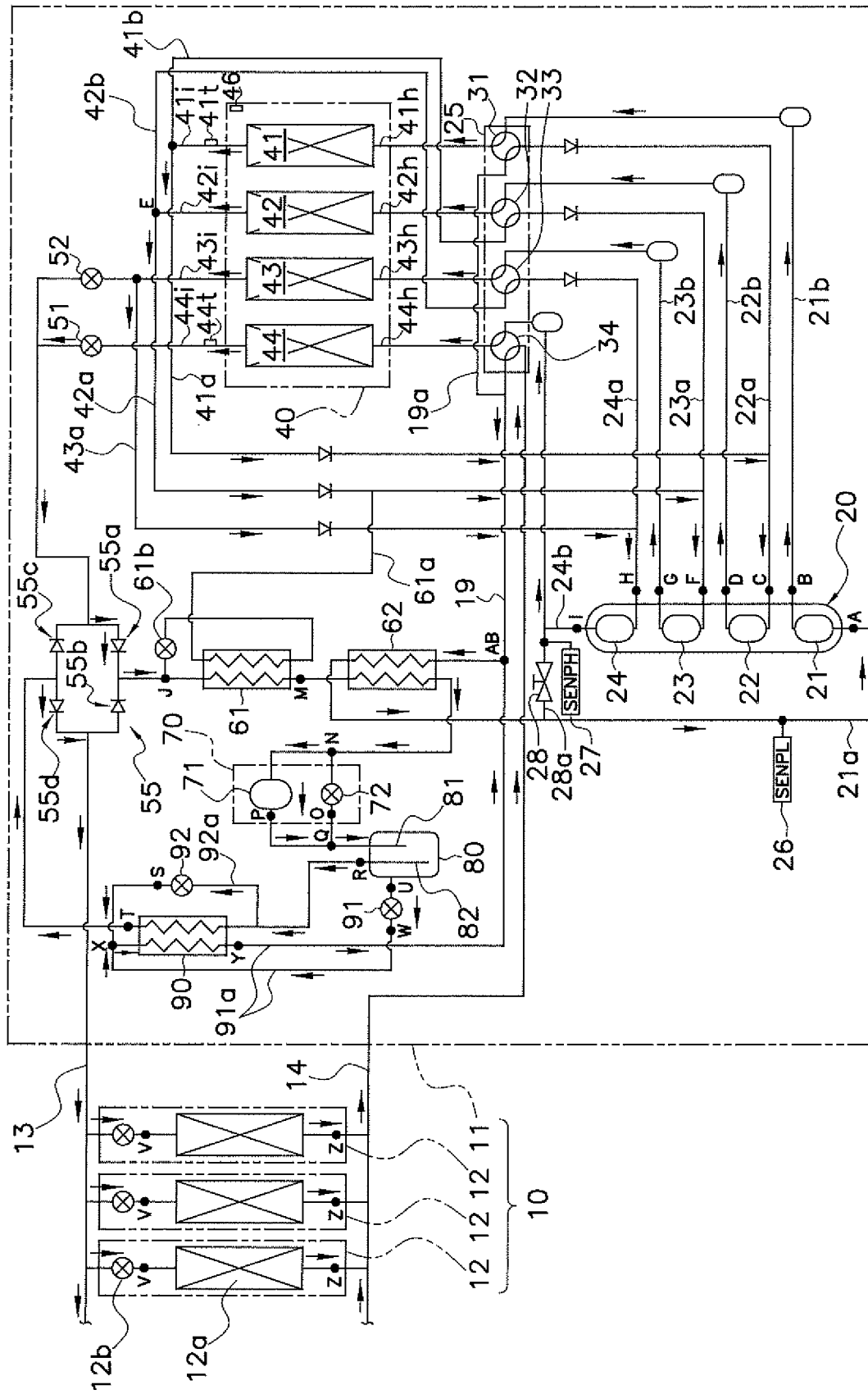


FIG. 2

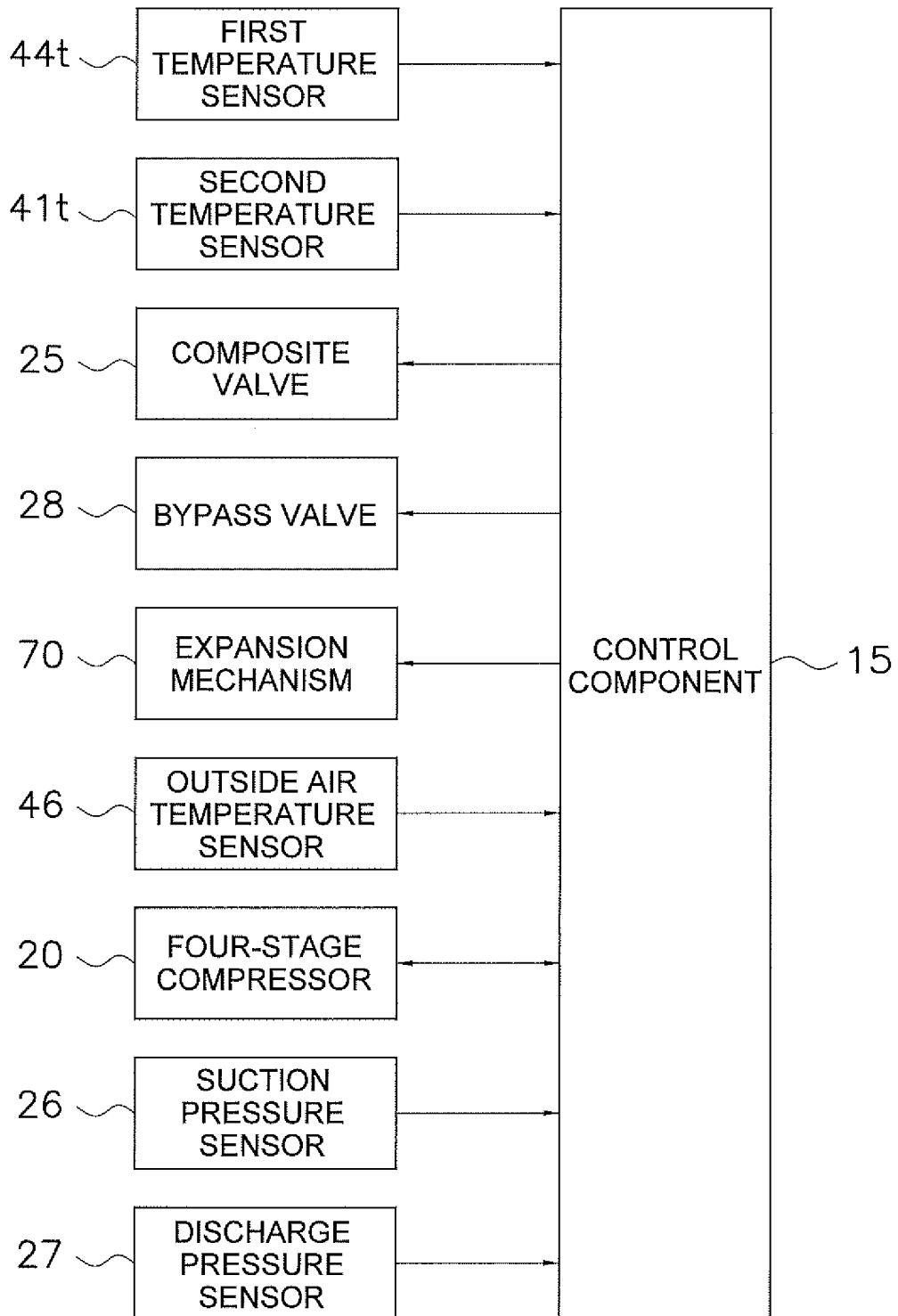


FIG. 3

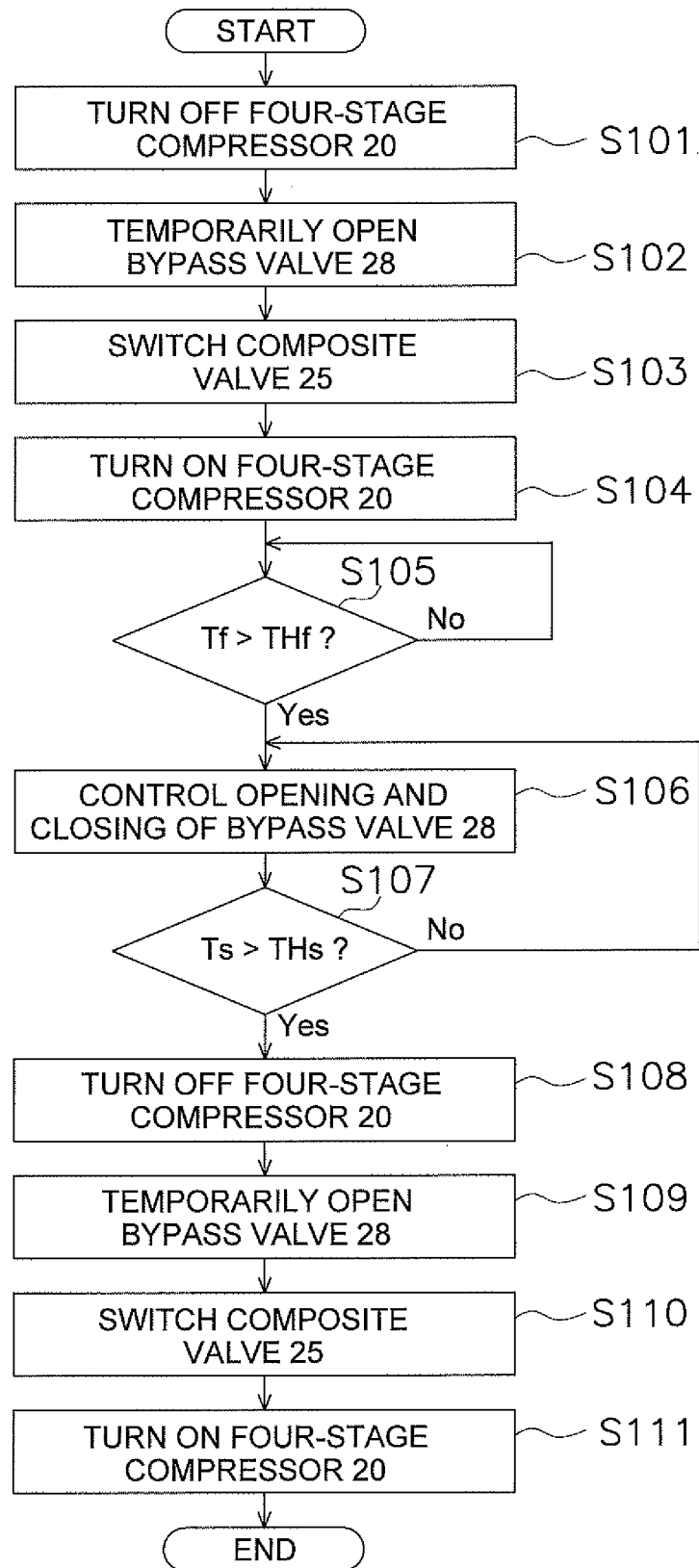


FIG. 4

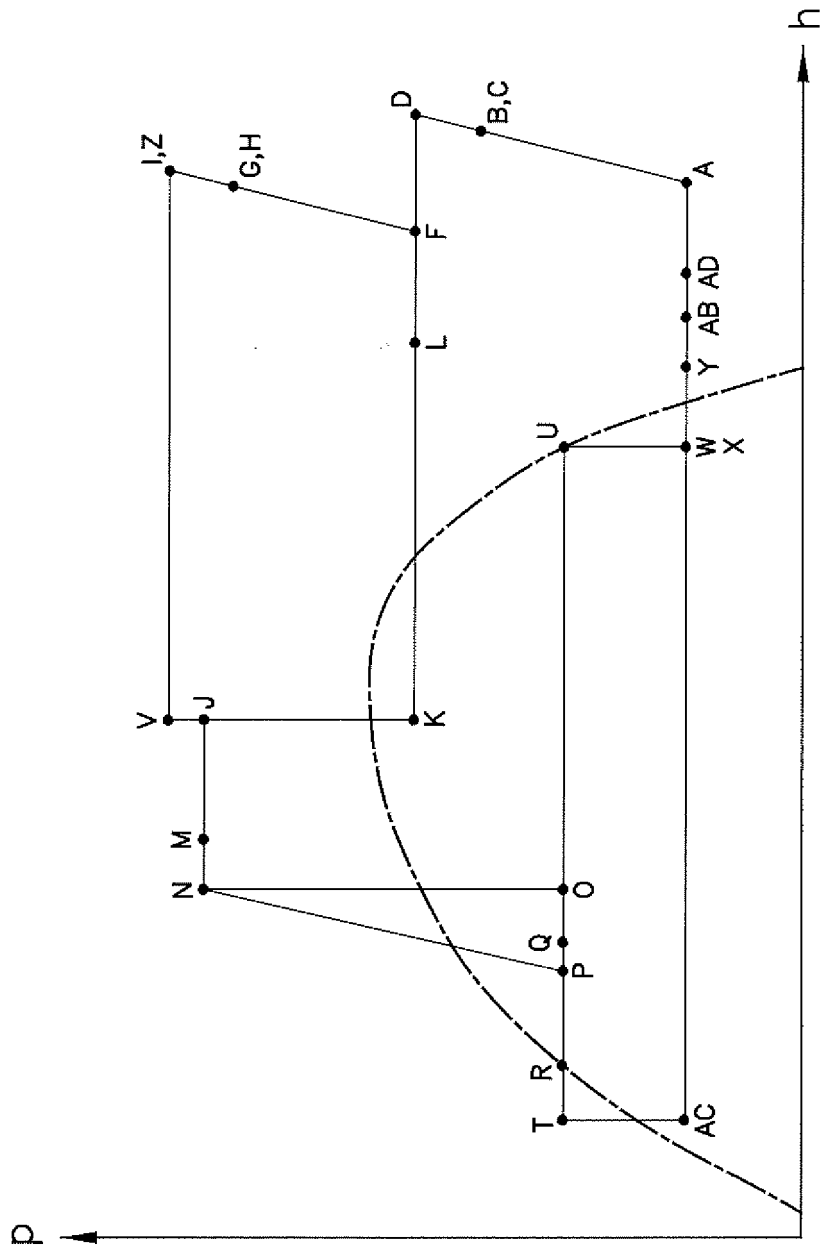


FIG. 5

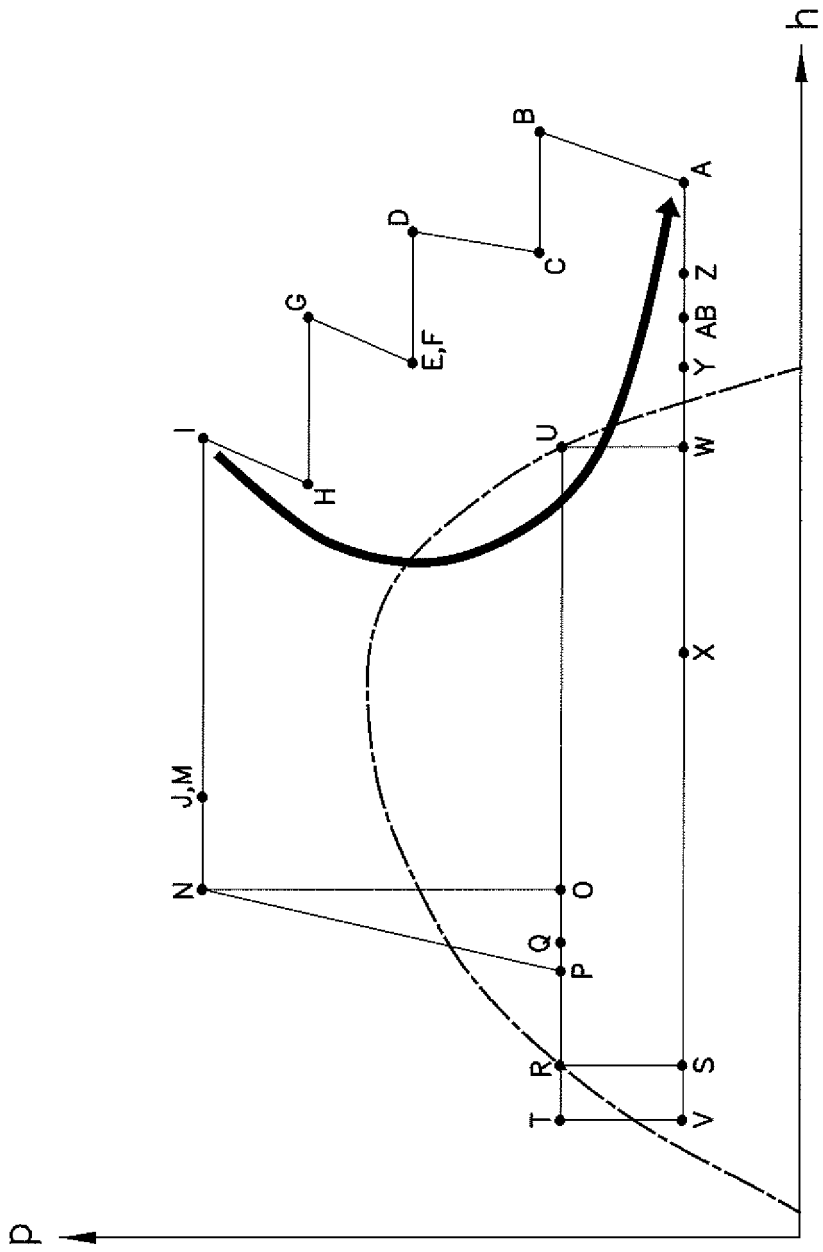


FIG. 6

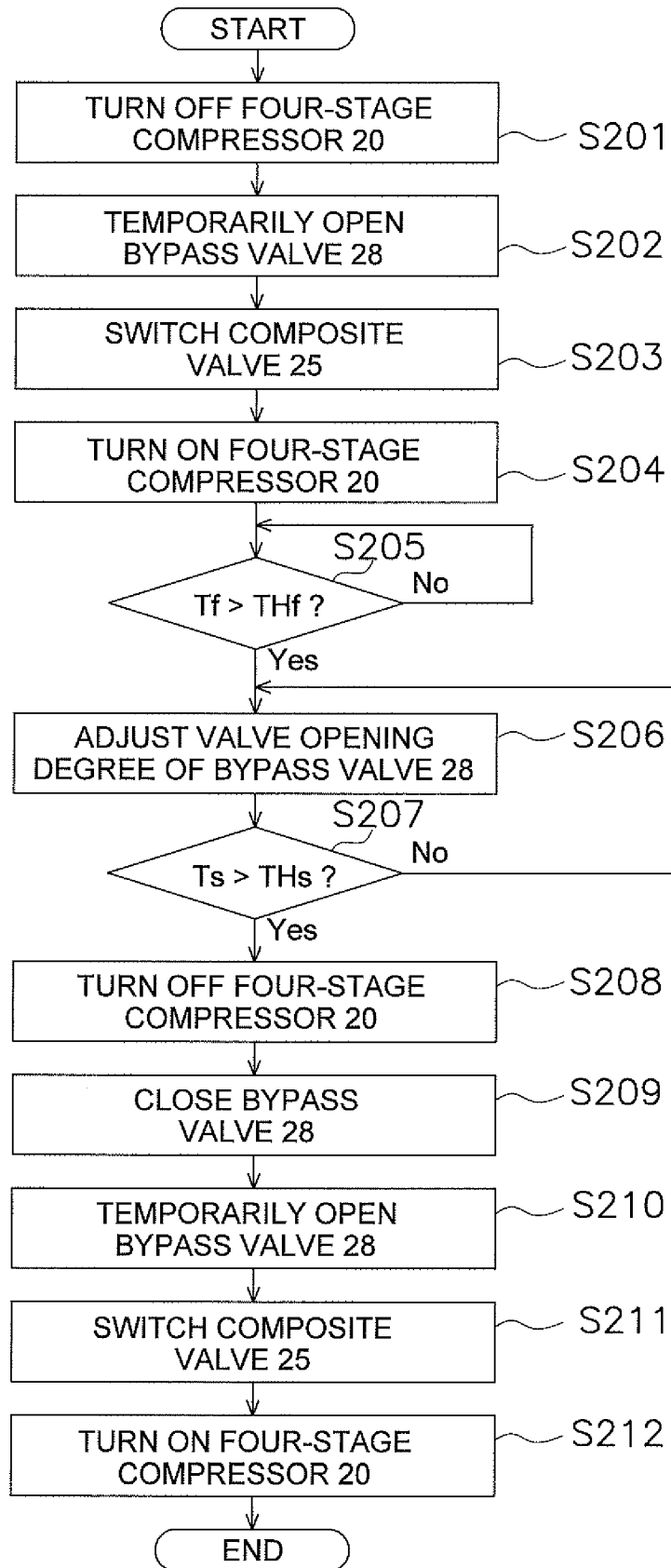


FIG. 7

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/006932

## A. CLASSIFICATION OF SUBJECT MATTER

F25B1/10(2006.01)i, F25B1/00(2006.01)i, F25B13/00(2006.01)i, F25B47/02(2006.01)i

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/10, F25B1/00, F25B13/00, F25B47/02

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 1996-2017  
Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

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. |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | JP 2013-210160 A (Daikin Industries, Ltd.),<br>10 October 2013 (10.10.2013),<br>paragraphs [0058] to [0088]; fig. 2, 4, 6<br>(Family: none)                               | 1-5                   |
| A         | JP 2015-132413 A (Daikin Industries, Ltd.),<br>23 July 2015 (23.07.2015),<br>paragraphs [0083] to [0133]; fig. 2, 4, 6<br>(Family: none)                                  | 1-5                   |
| A         | JP 59-93156 A (Sharp Corp.),<br>29 May 1984 (29.05.1984),<br>page 2, upper right column, line 19 to page 4,<br>upper right column, line 17; fig. 2 to 6<br>(Family: none) | 3                     |

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search  
02 May 2017 (02.05.17)

Date of mailing of the international search report  
16 May 2017 (16.05.17)

Name and mailing address of the ISA/  
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**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 2013210159 A [0002] [0122]